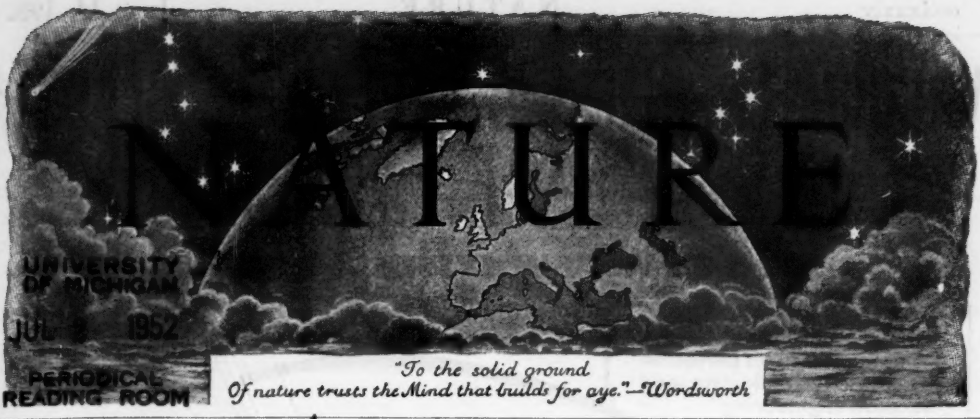

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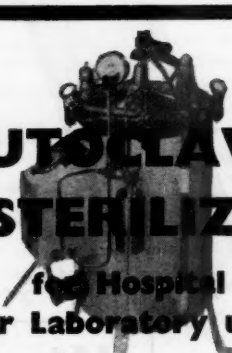

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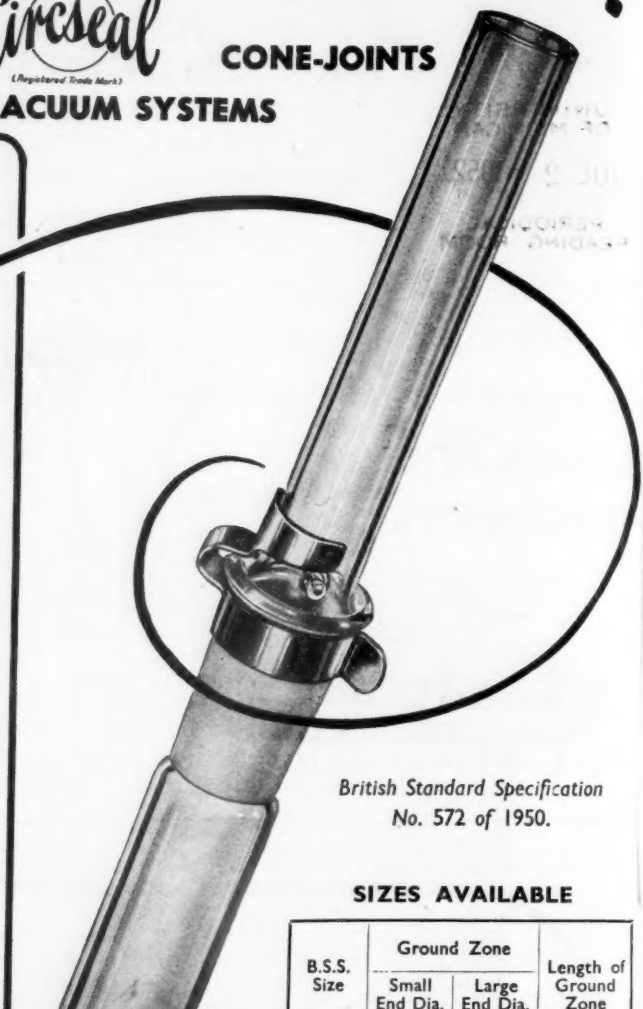

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SELECTION FOR UNIVERSITY EDUCATION

ALTHOUGH the recent report entitled "University Development", in which the University Grants Committee gave an interim review of the years 1947–51, shows little indication of the Committee's policy for the next quinquennium, the Chancellor of the Exchequer has since announced the extent of the recurrent grants to the universities of Great Britain for the period 1952–57. In doing so he made it clear that the increased grants would merely provide in general for the maintenance of existing activities, and that consolidation and adjustment rather than expansion is likely to characterize the next five years. Mr. Butler hoped that in the later years of the new quinquennium some new developments would be possible, particularly in science and technology, and he undertook, at a later stage, to consider whether he could give any useful guidance to the universities as to the scale on which they should frame their long-term plans.

Whether the new recurrent grant of £20 million, rising to £25 million by 1956–57, will permit the universities to maintain their present number of students may well be questioned ; and if the choice has to be between maintaining numbers and raising or even maintaining standards, there is little doubt as to which course the universities and the University Grants Committee will elect. That much is clear from discussions on the universities which are already proceeding, and it is all to the good that in so many quarters the right questions are being asked as to what are the proper functions of the universities in these days and what place they should take in the national life. The reports of recent 'productivity teams' of the Anglo-American Council on Productivity dealing with the universities and industry or with education and management, the discussion on education for leadership provoked, for example, by Dr. James's little book "Education and Leadership", Sir Walter Moberly's Walker Trust Lecture at St. Andrews and Lord Hankey's lecture last autumn on higher technical and scientific man-power, all help to stimulate the creative thought on which plans for the next quinquennium should be firmly based.

Notable contributions to this discussion and thinking are two articles, "Redbrick Revisited" in the *Cambridge Journal* for December 1951 and January 1952, in which Prof. D. W. Brogan passes once again over the contrasts between 'Oxbridge' and 'Redbrick', which Bruce Truscot emphasized in his well-known books ; he also draws on Prof. R. B. Charlton's portrait of the University of Manchester, and the article by J. F. Wolfenden "What are Universities For ?" in the *Fortnightly Review* of February 1951, which drew a number of interesting replies in the succeeding issue. Nor are the contributions entirely in debate, as Prof. W. A. C. Stewart showed in two articles on the experiment with general degree courses at the University College of North Staffordshire. Dr. A. L. Goodhart put forward a distinctive view of the functions of a university in his Haldane Memorial

Lecture at Birkbeck College, London, on May 7, the substance of which is printed on p. 986 of this issue.

Prof. Brogan's articles plead in the first instance for the historical approach which is illustrated so well in Prof. Charlton's book. He reminds readers that the problem of university development needs to be considered in the context of time, and no reader of Rashdall's great work can fail to appreciate the value of that factor. Prof. Brogan, indeed, accuses Truscot of disregarding it; less justly, he accuses Truscot of also neglecting the background of general social history. But though some of his criticism is over-stated and not always quite fair, Prof. Brogan does redress a balance or distortion which was due to Truscot's over-simplification of the issue when he focused his attention on the contrast between two groups only, 'Oxbridge' and 'Redbrick'. There are the special problems of the University of London; nor are those of the Scottish Universities or even of Durham quite the same as those which Truscot portrays for 'Redbrick'. Besides this, Brogan corrects the rather literary conception of research and emphasizes the place for, and duty of, reflective and critical thought which Sir Walter Moberly as well as Charlton and Alexander stressed.

Here, as in his discussion of certain of Truscot's proposals in regard to the tenure of university appointments and the reform of the examination system, Prof. Brogan supplies a useful corrective. He accepts the force of some of Truscot's criticism, but puts the other side; his articles help towards a clearer understanding of the true character and relations of the British universities. The second of the two articles is particularly valuable in this respect, for its analysis of the character and differences between Oxford and Cambridge and such universities as Leeds or Manchester does give some real guidance as to the lines upon which we should seek to guide their future development. Prof. Brogan recognizes that the newer civic universities have their own distinctive contribution to make in the pattern of British university life, and that it will not be made through deliberately imitating either Oxford or Cambridge, even if material and financial resources permitted. They cannot hope, and should not try, to break all the cords that bind their students to their homes, churches, clubs, schools and neighbourhood social life.

Truscot recognizes, perhaps even more explicitly than Brogan, one consequence of widening the basis of educational opportunity. An increasing proportion of university students are now drawn from homes where cultural standards are low or negligible. That is a problem which requires much more consideration in relation to university expansion than it has yet received. Brogan's article is a timely reminder that halls of residence for civic universities are by no means the only or even the first answer. Generous provision of libraries and reading rooms and better accommodation for social needs, whether in the unions or for different cultural needs, may be much more important and even more immediately practical. Finally, Prof. Brogan gives a fresh approach to the consideration of the regional responsibilities of the university which Prof. C. Dobrée initiated and Truscot only followed. Here he reiterates his point about location, and insists also that the cultural success of a university in a modern city depends in part on the existing cultural energy of the city, which the university may, of course, reinforce.

These two articles are, at least as much as Truscot's books, a blast against university complacency. Equally challenging is the article in the *Fortnightly Review* by the Vice-Chancellor of the University of Reading, and the more so in that he suggests that the answer to the question "What are universities for?" must come from the universities themselves, and indeed that all universities should not give the same answer. Mr. J. F. Wolfenden, moreover, concerns himself primarily with the teaching aspect, because this is the immediate practical problem, at least as regards the selection of students and the training they should be given. Original work, of all kinds and in all fields, he points out, remains one of the two prime duties of any establishment for higher education. But if the practical problem of selecting the right 24,000 students each year out of something like five times that number of applicants is to be handled with reasonable efficiency from the point of view both of public money and professional time, we must have some clear ideas of the type of student who should be admitted, the careers we expect them to follow and the teaching to be given to them.

It is not the outstanding student, with really first-class brains, who presents the problem. The real question is whether out of an annual age-group of some 600,000 there are enough left who on academic grounds deserve selection for the remainder of the 24,000 places. If the answer is doubtful, should we base the whole of our university procedure on the assumption that the academic is the one and only relevant criterion? Ought we not rather to consider, Mr. Wolfenden suggests, that the university has other functions besides that of serving as the place from which the learned professions draw their recruits? He argues that the universities would be doing a greater service to the community at large if they admitted to some of these places the young people who will be the leaders in agriculture, in commerce, the press, industry, radio, politics and local government than by reserving the places for some who are admitted to-day. The casualties would be no higher; but those who failed would carry away from the university something of more value than a degree and in their own way might well have enriched university life.

Mr. Wolfenden was careful to dissociate himself from any suggestion of lowering academic standards, and few of his critics suggested that he did. They were concerned rather with the practicability of selecting future leaders in industry or in society generally by any procedure for admission to a university which could be desired; but Prof. W. C. Atkinson, who roundly challenged any such possibility, recognized as clearly as Mr. Wolfenden the importance of ensuring that every undergraduate is exposed to the full play of the broadening, civilizing, character-forming influences which some students at present

escape altogether. Prof. H. Humphrey put it in another way when he suggested that training for life should come before training for leadership. But although it was differently expressed in the varied comments on Mr. Wolfenden's article and no specific proposals were advanced, there was a large measure of agreement that the prime task of a university is to supply the professions, industry and society generally not merely with the professionally and academically competent men and women required for diverse walks in life, but, above all—as it was put by the University Grants Committee in its report in 1936—with those whose minds are "richly informed, unsleeping in the exercise of critical intelligence, and imaginatively alive to the human issues underlying the decisions they may be called upon to make".

Just how the undergraduate is to be stimulated and trained to think strenuously about the great issues of right and wrong, of liberty and government, may well be a matter for difference of opinion. Prof. J. F. Baker, for example, emphasized the factor of experience, and suggested that postgraduate studies might yield a richer return if pursued three years after leaving the university on graduation. Sir Richard Livingstone, acknowledging the value of other qualities besides academic attainments, inclined to stress the contribution the universities could render in their extra-mural activities, such as adult education. Prof. W. R. Niblett emphasized that the process of 'civilizing' the individuals who make up a university must impart a sense of belonging to a living community, while Prof. D. Saurat's forthright plea for the abolition of the Finals Examination system was based on the contention that only by such a policy was it possible for university teaching to be given under conditions when the full civilizing and humanizing effect of any discipline was fully exerted.

We thus come back to the question of the primary functions and purpose of a university as visualized by the University Grants Committee in its last pre-war report, and they have been emphasized repeatedly by different participants in the discussion on university development during the past decade. It is of the utmost importance that this question of balance between general education and specialized training, between the educational function of a university and those which it fulfils as a community, furthers the development of culture and the advancement of knowledge. That is basic to our thought about the means by which particular developments, such as the expansion of technological education, should be furthered or the selection of students improved.

This is clearly recognized by recent contributions to the discussion on selection of students, both in articles contributed to the *Universities Quarterly* and the survey "The Selection of University Students", which Dr. F. W. Warburton has recently made for the University of Manchester School of Education*. We must first agree upon our goal before we can fruitfully discuss how to reach it, and agreement upon the purpose and function of a university is a first step towards the decision upon a suitable criterion of success at a university, which itself must precede any attempt to improve the present system. "Selection for universities," wrote Mr. Wolfenden in an earlier article, "will never be properly based until we have decided what universities are for"; and the most welcome feature of the current discussion is the evidence it affords that the universities are giving serious thought to these questions, and that the problem of selection, in particular, is now being examined in co-operation with the schools. Conditions which a satisfactory selection technique should fulfil, as seen by T. J. P. York, for example, agree substantially with Dr. Warburton's comments.

Dr. Warburton, in the survey just noted, points out that the question of selection is not only a major post-war problem of the universities, but also that it is likely to be a permanent problem. The main purpose of his pamphlet is to suggest, first, that research should be carried out into the efficiency of the methods at present used in selecting students, particularly advanced school-examination results, headmaster's reports, biographical material and the personal interview, using the class of degree awarded in the Finals Examination as the criterion of success; and secondly, that new methods, such as mental tests and group interviews, should be tried out with the borderline candidates. There is already evidence that the universities would benefit considerably if more rigorous methods of selection were adopted, and financial considerations may ultimately enforce such a policy. To make the selection of students as efficient as possible necessitates, as Dr. Warburton points out, undertaking a large-scale research, and the inquiry he proposes should be conducted separately in different university departments. The results of the follow-up would determine the final form of the various departmental selection procedures, which for routine purposes would be given only to borderline candidates.

By the time the results of such an inquiry permit definite conclusions to be drawn, further discussion might well have led to some agreement on the purpose and functions of a university, and possibly to the delineation of different functions for different groups or types of university, all serving the same broad fundamental purpose but in different ways. Inquiries, as Dr. Warburton suggests, might well enable us to adapt both old and new selection methods to particular purposes, and it is clear from the recent interim report of the University Grants Committee that inquiry and experiment into the technique of selection will have its firm support. If the serious thought which, as Dr. Warburton's survey shows, the universities are already giving to this problem is to have its full effect in ensuring that the nation receives a sound return from the considerable sums it invests in university education, there will also be essential the full support and co-operation of the schools, to which the articles in the *Universities Quarterly* testify, and also the interest and co-operation of their alumni in general.

* The Selection of University Students. By F. W. Warburton. (Publications of the University of Manchester School of Education, No. 1.) Pp. vii+46. (Manchester: Manchester University Press, 1952.) 4s. 6d.

EXPERIMENTAL AND THEORETICAL ELECTROCHEMISTRY

Textbook of Electrochemistry

By Prof. G. Kortüm and J. O'M. Bockris. Vol. 1, pp. xvi+351; 50*s*. Vol. 2, pp. xiii+353–882; 70*s*. (New York and Amsterdam: Elsevier Publishing Co., Inc.; London: Cleaver-Hume Press, Ltd., 1951.)

THE period following the theoretical and experimental establishment of the interionic attraction theory has seen the appearance of a number of treatises on electrochemistry and related subjects. The earliest of these was the German book by Falkenhagen (later translated into English); but apart from this the subject has been mainly written about by British or American authors. However, during the Second World War, Prof. G. Kortüm published "Elektrolytlösungen" (1941) and more recently "Lehrbuch der Elektrochemie" (1947), neither of which has received much attention in English-speaking countries. These books naturally follow to a considerable extent well-established lines; but they have several less usual features, notably the attention given to optical properties of electrolytes, electrolytic conduction in solids, melts and gases, and irreversible processes in electrolytes. These points, together with the good general exposition of Prof. Kortüm's writings, provide justification for making them more available to the English-speaking reader.

The volumes under review represent a translation and revision of the second edition of "Lehrbuch der Elektrochemie", together with enough additional material to produce a book approximately twice as large. Unfortunately, it must be said that the English edition does scant justice to the original, especially in some of the revisions and additions. The English is often clumsy by an exact adherence to the German (in phrases such as "the considered ion"), while in some instances the translation badly distorts the author's meaning. Outstanding examples of the latter are the rendering of "Grössen" as "volumes" in the second paragraph of p. 160, producing a meaningless sentence, and the translation of "lockernden Einfluss" as "attractive influence" at the bottom of p. 350, which exactly reverses the meaning and contradicts the rest of the paragraph. The chapter on thermodynamics has been largely rewritten, with unfortunate results. No clear account is given of the fundamentals of thermodynamics (for example, the definition of temperature is not mentioned), and there are many individual errors and ambiguities. Thus, after drawing a clear distinction between "volume work" ($p\Delta v$) and "specialized work", a statement is made (p. 52) implying that in the reversible expansion of a gas only volume work is done, the specialized work being zero. Similarly, the treatment of partial molar quantities (p. 58) does not distinguish between the amounts and concentrations of the components, and the account given of standard states and reference states (p. 82) is very likely to confuse even the most clear-headed reader.

The next four chapters follow the original fairly closely, but Chapter 7, on electromotive force, has been considerably modified. The chief criticism of this section (applying in part to the German edition also) is the emphasis given to individual electrode potentials and the activities of individual ionic species. The impression is given that our ignorance of these quantities arises only from experimental difficulties, and no mention is made of the fact that many authorities regard them as undefinable in principle and without practical value. Chapters 10 and 11, dealing with electrical phenomena at interfaces and irreversible electrode processes, have been considerably revised and expanded. It is in this latter field that Dr. J. O'M. Bockris's own contributions to electrochemistry have been chiefly made, and it is useful to have an up-to-date account of this difficult and growing branch of the subject. The variety of mechanisms proposed by different authors is well brought out, and the need for more experimental work of high quality is made clear.

The last 340 pages of the book represent material not contained in the German edition. There is a chapter on experimental methods in electrochemistry (by Roger Parsons), which is clearly written and contains much of value, though it may be doubted whether it is worth while to attempt a brief treatment of borderline techniques such as calorimetry and optical measurements. There follows a section of 160 pages devoted to tables of numerical data, compiled by B. E. Conway. It is not always easy to see the principles which have governed the choice of these data (for example, five pages are devoted to the densities of mixtures of fused salts); but many of the tables and the accompanying references should be useful. It is, of course, imperative that any such compilation shall have a high standard of accuracy, and this can only be judged by continued use. A few points I have noticed give evidence of some lack of care. The data in Table III, 3, are described as the parameters of the Debye–Hückel theory, but actually refer to the extended theory given by Robinson and Stokes. The data given in Table III, 48, for the transport numbers of sodium chloride and potassium chloride are listed under aqueous solutions, but actually refer to methanol–water mixtures. In Table III, 59, the values of pK for N-methylaniline and N-ethylaniline are described as "in alcoholic solution", though they refer to water, being extrapolated from measurements in alcohol–water mixtures of varying composition; conversely, the pK quoted for acridine was measured in 50 per cent alcohol, though this is not mentioned in the table. It is to be hoped that these samples are not representative of the reliability of the tables as a whole.

Volume 2 concludes with a collection of 120 numerical exercises (compiled by Roger Parsons and others), together with answers and hints for solution. These appear to have been well selected, and should be useful to students and teachers alike.

The work as a whole is attractively produced and easy to read, though it is marred by a large number of misprints; more than fifty were noticed in one reading of the first volume.

To sum up, these volumes contain a good deal of material which is of value; but their claim to be (to quote the dust-cover) "a solid and comprehensive summary of modern electrochemistry" is vitiated by a large number of blemishes, only a few examples of which have been given in this review. The impression is received that not nearly enough time and care have been devoted to the preparation of the English edition. Failing this, it would have been wiser to produce a smaller (and less expensive) work adhering more closely to Prof. Kortüm's original book.

R. P. Bell

A NEW BOOK FOR NATURALISTS

British Mammals

By Dr. L. Harrison Matthews. (New Naturalist Series.) Pp. xii+410+64 plates. (London and Glasgow: Wm. Collins, Sons and Co., Ltd., 1952.) 25*s*. net.

ANYONE attempting to survey our present knowledge of British mammals within the space of four hundred pages must be as much concerned with what to leave out as what to put in. Dr. Harrison Matthews must have been aware of this, as well as of the fact that no one person is competent to treat the subject equally authoritatively in all its aspects. He has wisely given us British mammals as he knows them best, which is mainly, though by no means entirely, from their physiology and anatomy. Early in the book he states his avowed intention not to deal with their habits, since these have been fully dealt with by previous authors. The result is a book which at first appears to be somewhat unbalanced; yet, as its story unfolds, it becomes increasingly evident that this treatment has achieved its end where a more co-ordinated and balanced planning might have succeeded less well. His method is to bring out in each group the salient points of interest.

The literature on British mammals, even within the past twenty years, is considerable; but most of it is not readily accessible to the naturalist. There have been several non-technical books on the subject; but the standard works of Millais and of Barrett-Hamilton and Hinton were still the main source of information. The present volume does not supersede these, but is complementary to them in precisely the way most needed.

The first chapter opens with a brief review of the literature since Wotton and Topsell, followed by cursory observations on taxonomy and genetics, the whole somewhat inappropriately headed "Mammal Natural History". In the next chapter, "Mammal Structure and Function", the author reveals his bias but equips the reader for his further reading with a survey of mammalian anatomy and the physiology of reproduction. The author's repeated return to the latter throughout the book constitutes one of its most valuable features, especially in the pages on delayed implantation. The various groups are then dealt with in systematic order. In his treatment of the Insectivora, the emphasis is on the physiology and anatomy of the reproductive organs, with notes on hibernation and the senses. One would have liked more detailed information on the mechanics of hibernation; and the omission of any reference to Adrian's work on the olfactory reactions of hedgehogs (and of rabbits) is a little surprising. In the biology of bats the author is on one of his favourite subjects and thus gives us an excellent authoritative account of their use of echo-location. Field naturalists may criticize the inclusion of a second, somewhat inadequate, key to the identification of bats; but presumably, knowing the great difficulty of identifying bats in the field, the author was over-anxious to be helpful.

The section on rabbits, hares and rodents contains most interesting material on plagues and population cycles, refection, seasonal changes of colour, reabsorption of embryos in rabbits, and an exposition of the origin and taxonomy of the subspecies of British voles and mice. These are most valuable chapters, though field naturalists will occasionally find difficulty in accepting some of the minor details, such as, for example, that the dormouse is "common in suitable places throughout the southern and western counties".

One most pleasing feature is the expression throughout the book of the changed attitude on the part of zoologists to the so-called vermin, the predatory carnivores, so important in the control of real vermin, yet for so long mercilessly persecuted. This is particularly evident in the pages devoted to stoats, weasels, badgers, martens, otters and foxes; and linked with it is a refreshing discourse on their relatively high mental equipment. In this and the next three chapters, on seals, deer and whales respectively, the author is at his best.

The book concludes with an account of the probable origin of the British mammalian fauna. The whole is rounded off with a systematic table, a list of the works referred to in the text, and a very detailed index.

Apart from very minor criticisms, the only adverse comment worth while is that the author tends to cast his net too wide and make too frequent incursions into non-British fields; but if this be a fault there is the compensation that our understanding of our indigenous mammals is broadened thereby. In any event, Dr. Matthews is to be congratulated on having brought together so much valuable information and interesting material in a book "which every naturalist must read".

MAURICE BURTON

INTRODUCTION TO THEORETICAL PHYSICS

Éléments de physique moderne théorique

Par Prof. Georges Guinier. (Bibliothèque de la science moderne.) Tome 1: Mécanique ondulatoire. Pp. 159. Tome 2: Structure de l'atome et du noyau. Pp. iii+161–309. (Paris: Libr. Bordas, 1949–50.) n.p.

THESE two books by Prof. G. Guinier are concerned chiefly with the theory and application of Schrödinger's wave-equation for systems of simply one or two particles. Thus in Vol. 1, after an introductory chapter on wave-particle dualism, which includes the relativistic treatment of the Compton effect and a fairly good discussion of group and phase velocity, Schrödinger's equation is introduced through the usual optical analogy and applied to the customary problems of a harmonic oscillator, rigid rotator, hydrogen atom and the passage of particles through barriers. Then, after introducing Bohr's correspondence principle and the uncertainty principle, the helium atom is treated, very nicely, and the book ends with a discussion of angular momentum, electron spin and the Pauli exclusion principle. The first chapter of Vol. 2 continues this story in discussing the periodic table, the hydrogen molecule and Van der Waals forces, these last being ascribed to the zero-point energy of coupled oscillators. Then there is a long chapter on applications to spectra—atomic, molecular and X-ray—including a discussion of the normal and abnormal Zeeman effects, the Paschen–Bach effect and even hyperfine structure, although, of course, there is no systematic treatment of the Dirac equation. Finally there is a chapter on nuclei, though the only serious theory here is Gamow's justification of the Geiger–Nuttall law.

Having thus briefly indicated the scope of these books, it remains to say something of the quality of the material in them. First, it should be said that there is a freshness about the physical exposition, even though it is often fragmentary, which is admirable. The vector composition of angular momenta is very clearly explained. There is also a welcome emphasis on numerical magnitudes. On the other hand, the books do have some quite serious defects which ought not to pass unnoticed in review. There are errors of commission as well as of omission. Of the former, among the more serious are the misleading application of the correspondence principle to give $\Delta l = \pm 2$ as selection rule for a linear symmetric molecule (p. 106), and the statement (p. 191) that quantum theory gives the frequency of a spectral line but no indication of its intensity or polarization. The table of nuclear spin moments (p. 251), moreover, is both arbitrary and inaccurate; and there are rather many printing errors in the mathematics. Of the omissions, three that spring to mind are the lack of diagrammatic illustrations of transmission coefficient formulæ, the absence of any general proof of the orthogonality of solutions of Schrödinger's equation, and, although the radial wave-function for a hydrogen atom is discussed in great detail, no indication is given that a second-order differential equation has two independent solutions. There is also, perhaps less surprisingly, a complete absence of formal perturbation theory; and there are no adequate references to primary sources.

Consequently, it seems to me that these are two excellent books to give to a first-rate mathematician about to turn to theoretical physics and who needs to get a good feel of the physical field, but that they are less satisfactory as a theoretical exposition for physicists.

Apparently these two volumes form only the first half of a longer work by Prof. Guinier which will deal also with the quantum theory of metals and the statistical and thermal properties of matter. It is probably on this account that the present books possess no indexes.

G. S. Rushbrooke

WHO ARE WE?

Science and Humanism

Physics in Our Time. By Prof. Erwin Schrödinger. Pp. ix+68. (Cambridge: At the University Press, 1951.) 8*s*. 6*d*. net.

In addition to their obligation to prosecute fundamental researches, the professors at the Institute for Advanced Studies at University College, Dublin, are bidden to deliver certain public lectures. This task —by no means a light one—Prof. Erwin Schrödinger regards as of major importance, and the result is this booklet, slender in bulk, but weighty in content.

About a sixth of the available space is introductory; the remainder is wholly devoted to an unfolding of twentieth-century physics and its implications for mankind. Let it be said at once that the sheer brilliance—and ease—of this veritable *tour de force* should not lull the reader into thinking that all is plain sailing: he is being taken through some very deep waters indeed by a skipper who knows the rocks and eddies so well that full speed can prudently be maintained.

Early on we are confronted with a flat denial that science is good because it is known to confer material benefits. Almost in the same breath (for the lecture style is conserved) comes a timely warning that specialist studies have scarcely any value in themselves; it is only in a grand synthesis of all the knowledges that mankind is likely to find satisfaction. Characteristically, too, there follows the observation that it is usually the man of science who imputes to the atomists of ancient Greece a fluke-like turn in their concepts of discontinuity in Nature, whereas the classical scholars take the more rational (and incidentally the more generous) view that the savants of Abdera knew full well what they were about.

The hard core of that which Prof. Schrödinger has to say is embedded in his discussion of individuality, permanence, the continuum, causality, and free-will. Because of the impossibility of attributing 'sameness' to a particle—say an electron—our sense of what is enduring must be due essentially to configuration (*Gestalt*) rather than to those entities themselves which, in a sense, are responsible for the arrangement. In a word, 'shape' may persist, but any attempt to label its elements is truly meaningless. Moreover, it may be noted that we are nowadays intent upon mastering, if we can, the secrets of form in the world around us, and that it is by no means only the men of science who are engaged in the search. Maybe philosophers and artists will contribute their quota (as they seem to be doing), and thus play their part in the grand symphony of an ever-broadening awareness.

We now brace ourselves to struggle with the idea of the continuum, and the formidable difficulties which it raises. The possibility of continuous observation cannot be upheld; there is not, in fact, a gap-less technique available for a full recording of natural phenomena. But wave-mechanics does provide a description of something upon acceptably classical lines by means of field equations. By such means, at least, it is believed that information is obtained about observed facts and their interdependence.

Perhaps the hardest portion of Prof. Schrödinger's lectures is that which deals with dyadic and triadic fractions, namely, fractions built upon the base 2 or 3 rather than upon the conventional base 10. The purpose is to exhibit the somewhat mysterious character of the continuum by a process somewhat akin to the method of exhaustions. A fine thread of academic pleasantry can be followed here, as an encouragement to the general reader. Otherwise, it would seem that the author's intention is mainly psychological in driving home these mathematical refinements.

Towards the close, there are two points of profound significance to notice. One is frankly æsthetic—the incongruity of invoking all the physical paraphernalia of quantitative *Methodik* to probe the subject–object relationship. The other is the emphasis upon interaction (as opposed to a type of unilateral play) in the same context. Both these considerations run parallel, odd as it may appear, to the main course of traditional theism, in demanding a certain balance between immanence and transcendence; and this, not only to avoid an arid deism on one side, and a vague polytheism on the other, but also to enable humanity to rise to full stature.

Prof. Schrödinger, for his part, faithfully interprets the epistemological aspect of this same thing as the task of science, namely, to seek an answer to the age-long question of Plotinus—"Who are we?"

F. I. G. Rawlins

Bibliography of Basic Texts and Monographs on Statistical Methods

(International Statistical Institute.) Compiled by W. R. Buckland. Pp. 84. (2 Oostduinlaan, The Hague, 1951.) 5*s*.

THE reader, who now sees before him a review of abstracts of reviews of books, may well ponder upon the proliferation of scientific literature. The introduction to this bibliography states that it consists of about a hundred basic texts on statistical methods published in English during the past decade. The work is designed for students, teachers, and practising statisticians, the aim being to cover in an all-round manner the theory and the main applications of statistical method, with particular attention paid to the practical usefulness of the books chosen. The general form of each entry is the routine publication details, followed by a list of chapter headings and extracts from reviews taken from four journals. The titles have been classified as follows: under general theory—elementary texts, intermediate texts, advanced texts and monographs; and under applications—economics, industry and agriculture, medicine and biology, and psychology and demography.

Cross-references would have been a help in this classification, in default of which the reader should consult other groups than those of his own immediate interest. The bibliography has netted most of the classics, but not all: for example, one such omission is F. Yates's "Design and Analysis of Factorial Experiments". For applications the net might have been cast wider: thus, genetical statistics is poorly represented, and there is no mention of forestry.

Those already having some acquaintance with statistical literature may be glad to have a list of works collected together; but the novice will probably be overawed at the size of the list and will regret that the compiler, in merely quoting extracts from reviews, has evaded the unenviable responsibility of suggesting where a beginner, according to his needs and ability, should start. J. M. HAMMERSLEY

Ion Exchange Resins

By Robert Kunin and Robert J. Myers. Pp. xi+212. (New York: John Wiley and Sons, Inc.; London: Chapman and Hall, Ltd., 1950.) 38*s*. net.

THE important advances of recent years and the wide and ever-growing variety of new applications have made it essential for every chemist, no matter what his particular field may be, to have at least a basic knowledge of ion exchange. There is, so far, only one book in the English language on the subject, and the present work is a welcome addition.

After a historical review, a description is given of the principles underlying ion-exchange behaviour. Much of the account is good, but too much space is given to the older empirical equations and not enough to the more recent work. Again, in describing the synthesis of ion-exchange resins, too much detail is given to the preparation of the older polycondensation resins and not enough to the newer vinyl-type polymers. The chapters on ion-exchange applications (and particularly the ones on water treatment) are the best. A very clear account is given of the problems one has to consider in the design of ion-exchange units and their practical solution.

A feature of this book is the very large number of diagrams. While these are generally helpful, they are often not labelled clearly enough for their exact meaning to be readily grasped. Taken in all, this book, in spite of some drawbacks, can be readily recommended. The printing and binding are good, and the price reasonable. D. REICHENBERG

The Diagnosis of Mineral Deficiencies in Plants by Visual Symptoms

A Colour Atlas and Guide. By Dr. T. Wallace. Second edition. Pp. vii+107+iv+312 plates. (London: H.M. Stationery Office, 1951.) 35*s*. net.

MORE than half of this book consists of colour photographs of plants suffering from deficiency or excess of different nutrient elements. These, together with descriptions of the characteristic appearance of affected plants, provide a means of diagnosing the causes of nutritional disorders occurring in field crops. The colour reproduction is much more accurate than in the first edition, and this should make diagnosis, especially by inexperienced persons, easier and more certain. More than a hundred new plates have been added, and for convenience of reference they have been re-grouped by crop species, instead of by nutrient elements.

The text is substantially the same as in the first edition. There are some amplifications to cover recent work (for example, on molybdenum deficiency), the bibliographies are enlarged, an appendix on rapid chemical methods of diagnosis is added to Chapter 3—a useful addition though strictly outside the scope indicated by the title—and the tabular description of deficiency symptoms in Chapter 4 has been rearranged and now refers to a larger number of crop species. All these changes enhance the value of a book that has already proved its worth to advisory officers, farmers and others concerned in growing food plants. D. J. WATSON

Organic Syntheses

An Annual Publication of Satisfactory Methods for the Preparation of Organic Chemicals. Vol. 31, 1951. R. S. Schreiber (editor-in-chief). Pp. vi+122. (New York: John Wiley and Sons, Inc.; London: Chapman and Hall, Ltd., 1951.) 22*s*. net.

THE forty-one preparations given in this volume cover the usual wide range of organic types: from them may be quoted, as representative examples, *p*-bromo- and *p*-ethoxy-phenylurea, 1 : 6-diiodohexane, 3 : 5-dimethylpyrazole, laurone, methyl *cyclo*propyl ketone, thiolacetic acid and triethyl phosphite. By a procedure based upon the original method of von Pechmann, coumalic acid is obtained in 70 per cent yield by the action of fuming sulphuric acid on malic acid; and *cyclo*hexene, reacting with potassium iodide and phosphoric acid, is converted to the extent of 90 per cent into iodo*cyclo*hexane. Pentaerythrityl tetrabromide (78 per cent) is obtained ingeniously from pentaerythritol by heating the benzenesulphonate in diethylene glycol with sodium bromide. Another preparation of special interest is that of *dl*-4 : 4′ : 6 : 6′-tetrachlorodiphenic acid, which can be resolved into stable enantiomeric forms, owing their optical activity to restricted rotation about the single bond joining the two benzene rings. The preparation departs from anthranilic acid, and depends upon the successive application of chlorination, diazotization and reduction. The index to this volume covers also Vol. 30 of this series.

JOHN READ

NATURE AND PURPOSE OF A UNIVERSITY*

By Dr. A. L. GOODHART
Master of University College, Oxford

IT was in the second half of the nineteenth century that a greatly increased demand for university education spread throughout Great Britain. This followed naturally on the provision for general elementary education; but it was also the result of a realization that a university education was not merely an ornament but also of practical value. No man played a greater part in furthering this idea than did Richard Haldane. It is just fifty years ago, in 1902, that his book of essays, "Education and Empire", was published. In it he made an eloquent plea for the establishment of more universities in the great cities of Britain. He asked why Liverpool, Manchester and Leeds should not have universities of their own. He said: "Courage, energy and enterprise are in these modern days of little more avail against the weapons which science can put into the hands of our rivals in commerce than was the splendid fighting of the Dervishes against the shrapnel and the Maxims at Omdurman". He pointed out that the brewing and the coal-tar colour industries, which at one time had been the virtual monopoly of Great Britain, had been largely taken over by Germany owing to the development of universities in that country. That development was due to the fact that their universities had a double aim: pure culture on one hand and the application of the higher knowledge to commercial enterprise on the other. "It is evident," he said, "that the reason of popularity of the Universities is not that they are free, for they all charge fees, but that they help the students to a position in life." In an even more prophetic manner he predicted that the United States would make a striking advance in the years to come, not only because of her natural resources but also because of the American enthusiasm for universities. He said: "You have only got to look at the books America is beginning to pour out on abstract subjects . . . to see that in abstract knowledge as in commerce America is going ahead by leaps and bounds. Why is it? I put it down, partly at least, to the development of higher teaching that has taken place in America".

In the fifty years since Lord Haldane delivered his lectures, the truth of his statements has been strikingly demonstrated. To-day the lesson of the Second World War has taught us that the armed forces of a nation depend to an ever-increasing degree on the man of science in his laboratory. We are beginning to see that the university can make an essential contribution to every branch of national life. The result has been that in the past few years the number of university students has almost doubled in Great Britain, although in proportion to the population it is still lower than in many other countries. This great increase in number has brought again to the forefront the question which is always concerning those who are responsible for the universities. What is the true purpose of a university? The number of students who should have the privilege of university training ought not to depend either on the physical capacity of the existing universities, or on the number of available teachers, for both can be increased if necessary. We can only decide how many students ought to be university men if we are clear in our own minds what is the function of a university. This will therefore be the subject of my lecture.

In that much-discussed recent book entitled "Red Brick University", the author defines a university as "a society which devotes itself to a search after knowledge for the sake of its intrinsic value". He holds that the primary purpose of a university is research, and that teaching, although of great importance, is not an essential function of a university. I myself would reverse his statement; to my mind a university is primarily and always a teaching institution. In every university that is worthy of the name we find, of course, that research work of the greatest importance is being done; but this is not its essential purpose. It is true that the teacher who does no research work of his own will probably be of less value than one who is making an original contribution to knowledge; but the university teacher ought to be a teacher in the first place and only secondarily a researcher. There are, of course, exceptions to this rule; but no university can support more than a limited number of them.

I begin therefore with the proposition that a university is a place for teaching. This, however, will not give us a satisfactory answer, for there are many other places besides a university where men are being taught. The purpose of a university is, I believe, to develop the complete man in the sense in which this phrase was used by the Greek philosophers. The complete man is not the man who has the most knowledge, but he is the one who is best equipped to acquire it. It is not what a man has learned but how he has learned it that matters. Just a century ago, Cardinal Newman, one of Oxford's most famous sons, described the purpose of a university education in these words: "A habit of mind is formed, which lasts through life, of which the attributes are, freedom, equitableness, calmness, moderation, and wisdom; or what in a former Discourse I have ventured to call a philosophical habit. This then I would assign as the special fruit of the education furnished at a University as contrasted with other places of teaching or modes of teaching. This is the main purpose of a University in its treatment of its students".

This habit of mind does not depend on the particular subject which the student is studying; it is clearly applicable to philosophy, history, law, economics and to the natural sciences. On this point it is, I think, unfortunate that to-day we tend to draw a distinction between the arts on one hand and science on the other, as if they represented two conflicting methods of thought. This error is due in large part to the scientists themselves, who seem to claim some superior virtue for what they call the scientific method. On analysis this does not seem to mean more than that a student must be logical and accurate in his thought processes. But this is as true of the art student as it is of the scientist. Our ancestors were on sounder ground when they spoke

* From the Haldane Memorial Lecture delivered at Birkbeck College, University of London, on May 7.

of science as a natural philosophy. We are beginning to realize the truth of this, for many of our most distinguished modern philosophers, such as Bertrand Russell and Alfred Whitehead, began as scientists or mathematicians before they turned to philosophy. I am not denying, of course, that there is a distinction between science and the arts, but I do claim that the basic mental training of the science scholar and the art scholar is the same. If we fail to recognize this then we shall fail to understand the true purpose of a university, and what it can give to its students.

It is, however, of little value to talk of university training in a general manner. Just as the purpose of army education is to develop the qualities of discipline and courage, so we are faced with the question whether there are any qualities which are essentially those of a university man. Ought we, the teachers, to have these particular qualities in mind whatever may be the subject-matter we are trying to teach?

Before I try to answer this question, I want to make it clear that I do not think that an accumulation of facts, however valuable they may be, constitutes a university education. As university teachers we must remember that we have only three or four years in which to educate our students. The number of facts which we can teach them is necessarily limited, and may be of small value. But when we turn from the teaching of facts to the inculcation of ideas, we find that three or four years are not too short in which to influence a receptive mind in its approach to the problems of a whole lifetime.

What then are the particular qualities which a university ought to impart to its members so as to give them what may be called the university stamp? What are we entitled to expect from the university man who has undergone its intellectual training? The list is not a long one. It consists of two qualities only, but they are of transcendent importance: the first is clarity of thought, and the second is intellectual curiosity.

Clarity of thought is essential because the scholar who is not accurate, whose ideas are confused and uncertain, is not a true scholar. It was this emphasis on clarity of thought which was the major contribution made by the medieval universities. We have been taught to believe that those trained in scholasticism spent their time in discussing such problems as "How many angels can stand on the point of a needle?" It would be difficult to paint a more inaccurate picture. Scholastic education was a magnificent instrument for the training of the mind. In his "History of the Medieval Universities", Prof. Rashdall said: "It was not the wont of the practical men of the Middle Ages to disparage academic training. . . . In a sense the academic discipline of the Middle Ages was too practical. It trained pure intellect, encouraged habits of laborious subtlety, heroic industry, and intense application, while it left uncultivated the imagination, the taste, and the sense of beauty. It taught men to think and to work rather than to enjoy. . . . The greatest service of the medieval universities to mankind was simply this, that they placed the administration of human affairs—in short, the government of the world—in the hands of educated men. The actual rulers—the kings or the aristocrats—might often be as uneducated or more uneducated than modern democracies, but they had to rule through the instrumentality of a highly educated class".

I believe that that emphasis on clarity and accuracy of thought may still be regarded to-day as an essential part of university training. When I first went to Oxford in 1930 one of the best-known tutors there was H. W. Joseph, of New College, whose books on logic are still authoritative. His pupils have made a remarkable record both in the academic life at Oxford and in their later careers in London. I once asked him what his method of teaching was, and he said to me: "When a man comes to my rooms to read me his first essay, I stop him after he has read the first paragraph and say to him, 'What exactly do you mean by that?' When he brings me his last essay and reads the last paragraph, I say to him, 'What exactly do you mean by that?' Between the first and the last essay I hope that I have taught him something of permanent value". I have taken my illustration from the Oxford tutorial system, but the point is just as true when applied to the lecture system which exists in most other universities. If the professor answers all the questions in his lectures, even if his answers should be correct, then he deprives his students of an essential mental exercise. On the other hand, if he encourages his students to think for themselves by presenting both sides of every difficult problem, then he is giving them the training which will lead to true scholarship. That does not mean that the professor need be neutral, for that is often a form of dullness, but he must be fair. He must make it clear that he is not asking his students to accept his statements without further consideration: he must insist that it is their duty to decide the problem themselves and that they must achieve an answer which they themselves find satisfactory.

I believe that to-day in our national life there is no quality which is more essential than is this clarity or honesty of thought. It has been said with some truth that the danger to-day is the cult of the cheap, the shoddy, and the false. That has always been a danger; but mechanical developments, such as the wireless and television, have made it a more immediate one for us. It is the duty of the universities, who are the trustees of the great traditions of the past, to make it clear that the half-truth is the deadly academic sin.

The second quality which it is the purpose of a university to develop in its students is an inquiring mind. This is the major contribution which the modern university has made to education, for we now question our original premises instead of accepting them on authority alone. In Britain the modern approach is frequently ascribed to the philosophy of Francis Bacon; but it is, of course, part of the whole Renaissance attitude towards life. It is in this emphasis on inquiry that we find the essential difference between a university and a purely technical school. There has, I believe, been confusion on this point, because in the debate which has raged around the distinction between a university and a technical school the word 'technical' has been used in two different senses. When we turn to the Oxford Dictionary, we find that in one sense 'technical' is defined as "appropriate or peculiar to or characteristic of a particular idea, science, profession or occupation". In this sense such a technical school is a proper part of a university, because the fact that it teaches only one particular art or science does not, of course, deprive it of its university standing. Thus no one would argue that such a school as the famous École des Beaux Arts in Paris ought not to be regarded as of university calibre, for it is concerned with the fundamental concepts of art. On the other hand, the Oxford Dictionary gives a

second meaning to the word 'technical', which reads "the formal and mechanical part of an art". In this sense, of course, a technical school is not a proper part of a university, because a university does not and cannot limit its interest to mechanical skill however important this may be. The university teaches its students *why* a thing is done, while such a technical school teaches him *how* a thing is done. Or, in other words, the university inculcates a method of thought, whereas this type of technical school develops a special skill. This distinction does not depend on the subject-matter which is being taught, but is based on the manner in which it is being taught.

The highest form of education consists in encouraging a man to ask questions. Perhaps as a lawyer I am naturally interested in this method of education, because the famous cross-examiners in the history of the courts of Great Britain have not been those who scattered questions wholesale, but those who knew how to direct their examination to the salient point. It may have been his legal training which encouraged Lord Haldane to place so much emphasis on the search for truth. It is interesting to note that in his essays he twice makes the same reference to the German philosopher Lessing. He said: "It was Lessing who declared that were God to offer him the Truth in one hand and the Search for Truth in the other, he would choose the Search. He meant that, just as the Truth never stands still, but is in its nature a process of evolution, so the mind of the seeker after it can never stand still. Only in the process of daily conquering them anew do we, in this region also, gain life and freedom". But this life and freedom of the mind cannot be gained without a struggle. The years which a man spends at a university should be those in which he is prepared, as was his medieval brother, to put forth every effort. This inquiring mind requires intellectual courage, because every question is a kind of adventure and in the nature of a challenge. The man who does not feel a sense of excitement when faced with such a challenge has no place in a university.

That brings me finally to the most difficult problem with which the universities throughout the world are faced to-day. Ought we to admit all those who are seeking to enter our doors? The recent development of the natural sciences has been one of the causes which has brought about an astonishing increase in the number of applicants; but there seems to be an almost equal demand in the other subjects. This is admirable in so far as those students who are seriously seeking a university education are prepared to undergo its discipline; but it is dangerous if what they hope to receive is nothing more than a mechanical training. If we in the universities lower our standards, we shall be sacrificing an essential part of our civilization. But if we make it clear that we are maintaining our standards, then we ought to exclude no one who wishes to receive a university education. We ought so far as possible to take as many students into our existing universities as they are capable of receiving, and if necessary we ought to be prepared to increase the number of the present institutions. It is sometimes said that if we increase the student population then we will not be able to find a sufficient supply of adequate teachers; but here as elsewhere I believe that the supply will be able to satisfy the demand, if they are paid an adequate stipend. It is also said that if the number of university graduates is increased then they will find difficulty in obtaining employment. This will be true only if university education is inadequate, because, as Lord Haldane emphasized again and again, there is no field in which the university man ought not to take a leading part if he is adequately trained. This means that at the universities we must not be afraid to teach those subjects which may be said to be of practical value. It is *how* we teach and not *what* we teach that makes a university. No one would advocate a university course in cooking; but if we regard it as the science of dietetics, then it is obviously of the greatest importance to the life of a nation. Mr. Justice Holmes, of the United States Supreme Court, once said that a university law school was a school in which law was taught in the grand manner. That grand manner can be applied to other subjects. I think that it is interesting to find that in recent years the Harvard School of Business Administration has become of major importance in American commercial life. Ought we not to consider the establishment of a similar institution in London, which is the centre of the banking and commercial life of the world? Why, for example, should we be ready to teach company law at a university, but ignore the system of accounting with which that law is so intimately concerned? We should regard all forms of human knowledge as our province, even those which are of practical value.

To-day there is no branch of social or economic life which can rest solely on experience. In facing the changes which are inevitable we must depend on the adventurous, inquiring mind, which has also been trained to be accurate. It is the function of the university to develop men of that calibre. I believe that Lord Haldane was right when he demanded, fifty years ago, that we should have more university students in Great Britain, so that they could compete with the university-trained manufacturers and industrialists in other countries. That is a duty which the universities cannot ignore. It is not enough, as he said, for the scholar to look down on those engaged in the battle of life. He must be prepared to play an active part himself. I cannot do better than to close with the words Lord Haldane used in his rectorial address to the University of Edinburgh in 1907: "Rather does the University exist to furnish forth a spirit and a learning more noble—the spirit and the learning that are available for the service of the State and the salvation of humanity. The highest is also the most real; and it is at once the calling and the privilege of the teacher to convince mankind in every walk of life that in seeking the highest of its kind, they are seeking what is also the most real of that kind. Whatever occupation in life the student chooses, be it that of the study or that of the market-place, he is the better the greater has been his contact with the true spirit of the University".

INTERPRETATION OF GRAVITY ANOMALIES

A GEOPHYSICAL discussion on this subject arranged jointly by the Royal Astronomical Society and the Geological Society was held on February 22, with Dr. G. M. Lees, president of the Geological Society, in the chair. The principal contributors were B. C. Browne, P. Evans and N. L. Falcon; and Dr. T. C. Richards, Brigadier E. A. Glennie, Dr. J. de Graaff Hunter, Dr. J. Phemister, D. R. Brown, Dr. A. H. Cook, Dr. R. Tomaschek,

Prof. S. H. Hollingworth and M. W. Strong took part in the discussion.

Mr. B. C. Browne gave a general description of the distribution of the major anomalies of the earth's gravitational field. The earth is an oblate spheroid, and calculation shows that the figure of the earth is nearly the same as for a self-gravitating liquid sphere in rotation, the value of g at the equator being less than that at the poles. The earth's surface is divided into continents and oceans: about one-third of the former above sea-level averages 840 metres in height, and one-half of the latter is deeper than 3·8 km. Since water has a density of 1 and rock approximately 2·7, we should expect g over oceans to be about 300 milligals less than over continents, but in fact the gravity is almost exactly the same over both. On a freely rotating body the average value of gravity over the two hemispheres must be equal, hence g over the Pacific must be equal to g over the opposite hemisphere, which indicates more mass below oceans than continents. The process of mass compensation is called isostasy.

In addition to the evidence that major features—oceans and continents—are compensated by having different types of crust, gravity surveys have shown that large topographic features—mountain ranges and sedimentary basins—are normally compensated by variations in thickness of the crust. If they are not, strains in the crust will result and tectonic movements are to be expected; but in normal quiescent conditions isostasy is expected to hold over large regions. The two main interpretations of the isostatic theory are by Pratt and Airy, and depend on whether a mountain range is supported by having a lighter rock column to a depth of about 100 km. than under the plains on either side, or on whether a mountain range has roots of light rock protruding downwards into a denser medium. By making these assumptions, the reason for gravity deficiency under many mountain ranges can be understood.

The gravitational field in the United States has recently been analysed by Dr. Tsuboi, of the Geophysical Institute, University of Tokyo, and, by a system of harmonic analysis of comparing components of topography and gravity, he concludes that those with wave-lengths greater than about 320 km. show correlation. Shorter wave-lengths do not. This result is in general agreement with those of Vening Meinesz, who deduced a diameter of regionality of about 300 km. for the compensation of the Hawaiian Islands.

The conclusion is that major features (oceans, continents) are compensated by different types of crust and that large topographic features (mountain ranges, basins) are normally compensated by variations in thickness of the crust.

Mr. P. Evans described how in areas of thick sediments of low specific gravity, as in Eastern India and Burma, a correction can be made to compensate for varying thicknesses of these light sediments over a metamorphic basement. Such geological corrections can amount to 75 milligals, but, even after they are made, large anomalies remain along the Himalayan and Burman mountain front. Mr. Evans thought that the isostatic theory of Pratt—and India is its birthplace—is entirely unrealistic in its geological conception and in its treatment of compensation of topographic features. The theory, despite its lack of geological or physical plausibility, has been developed by Hayford and Bowie and applied to many parts of the world, and calculations on the exact depth of compensation are merely mathematical fantasies. The theory of Airy, Mr. Evans continued, is much to be preferred, as geologists expect mountain ranges to be associated with some change in mass distribution at depth. He objected to the assumption that an isostatic correction which reduces an anomaly is a desirable one regardless of its physical meaning. A geological correction, however, should be first applied whatever its effect.

Mr. N. L. Falcon discussed the value of detailed gravity surveys in areas where geological conditions are partly known and partly unknown, provided there is a chance that the problem is amenable to gravity interpretation. Extensive gravity surveys have been carried out in Great Britain in the search for oil, and in concealed Carboniferous areas corrections can be made for the thickness of the unconformable cover. After this is done, the resultant gravity anomalies indicate the Carboniferous structures. The Formby area in Lancashire is an outstanding example of the value of gravity work for solving a local problem, predictions having been confirmed by subsequent drilling.

Dr. T. C. Richards thought that isostasy is true in some parts of the world but not in others; some recent work in New Guinea indicates that isostasy can apply in the mountain belt, but along the north coast results are inconsistent. In Persia the mountain belt does not seem to be isostatically compensated.

A method whereby residual anomalies can be found by removing the regional effect was described by Mr. D. R. Brown. The Hayford–Bowie isostatic reduction, although geologically unreasonable, does not differ much from those of Airy–Heiskanen or Vening Meinesz, the isostatic anomalies all showing the same main features. There are some regional trends which cannot be explained on any isostatic hypothesis.

In summing up, Dr. G. M. Lees said that in continental areas there are so many exceptions where the isostatic principle does not apply that he doubted its validity. Some mountain ranges show gravity deficits, others the reverse. The large positive anomalies of Cyprus and in the Oman mountains of Arabia, for example, cannot be explained on any theory of isostasy. To some extent the problem turns on the strength of the earth's crust and the degree to which additional loading can be supported. One frequently quoted support for isostasy is the assumption that the recent rise of Scandinavia is the consequence of the disappearance of the great Ice Age ice burden. This is a most unsafe deduction. Few coastlines in the world are static; they are either rising or falling, but for no ascertainable reason and certainly not because of the removal or addition of a recent burden. It is commonly asserted that a sedimentary basin sinks isostatically because of its load of sediments, but, said Dr. Lees, is it not rather that the sinking from some quite different cause has allowed the sediments to accumulate? He believed that crustal deformations are the consequence of contraction of the earth and not of convection currents in an imagined sima. The contraction may be due to heat loss, perhaps combined with some physical phase-modification at depth, as the high-pressure researches by Prof. P. W. Bridgman suggest to be possible.

As an aid to geological exploration, gravity surveys have proved to have considerable value where conditions are favourable; but their interpretation inevitably requires assumptions which may or may

not be valid. The principal value is in detecting local anticlinal structures in areas of thick sedimentary cover; but attempts to use the results for regional analysis are often unsuccessful owing to the difficulty of differentiating the effect of a changing thickness of sediments from that of a deeper-seated regional cause.

The development of portable gravimeters during recent years has led to a notable increase in gravity surveying throughout the world. A vast amount of new and important information is coming forward, and much of it still awaits adequate geological and geophysical analysis and interpretation.

LARGE-SCALE MOTIONS OF IONIZED CALCIUM IN THE ATMOSPHERE OF A GIANT STAR

By A. McKELLAR and G. J. ODGERS
Dominion Astrophysical Observatory, Victoria, B.C.
and L. H. ALLER and D. B. McLAUGHLIN
Observatory, University of Michigan, Ann Arbor, Mich.

THE star 31 Cygni, magnitude 4·0, was announced[1] in 1898 as having a composite spectrum, and was later found by W. W. Campbell[2] to be a spectroscopic binary. In 1936 W. H. Christie[3] obtained an approximate spectrographic orbit for the brighter component, and in 1944 Miss Vinter Hansen[4] published a more definitive orbit. The system consists of a cool giant *K*-type star and a relatively small hot *B*-type star, which revolve about their common centre of gravity in a period of about 3,800 days. (The *K*5 component, with its minimum diameter of 150 times that of the sun and an absolute magnitude (judged by spectroscopic criteria) at least as great as −1, should probably be classed as a supergiant. However, for convenience, it is referred to as giant star in this account.) In 1950, D. B. McLaughlin[5] reported that three spectrograms, obtained in 1941, indicated an atmospheric eclipse of the *B*-star.

It is rare to find eclipsing binary stars with components differing widely in temperature but of equal brightness at some wave-length in the ordinary photographic region. Only three were known previously, namely, ζ Aurigæ, *VV* Cephei and 32 Cygni. Their special importance arises from the fact that the hotter component is relatively small. Thus, as this component, exhibiting an almost continuous spectrum, travels behind the atmosphere of the giant star, it provides effectively a point-source probe for analysing the extended atmosphere by means of absorption spectroscopy. We can now say, anticipating the 1951 results outlined below, that the primary star of 31 Cygni has a diameter at least 150 times that of the sun. Its atmosphere extends at least another 150 solar diameters from its surface. The small *B*-type component has a diameter only about five times that of the sun.

The available evidence predicted an eclipse of 31 Cygni late in 1951. Spectrographic observations made at Victoria, B.C., with the 72-in. reflector and at Ann Arbor, Michigan, with the 37-in. reflector, showed atmospheric eclipse effects by June 1, 1951; these increased, slowly at first, but rapidly from late in July, until total eclipse began on August 12. The small hot star emerged from totality on October 12, and the spectrographic phenomena of the ingress took place again in reverse order; on January 8, 1952, a faint chromospheric *K*-line still appeared in the spectrum.

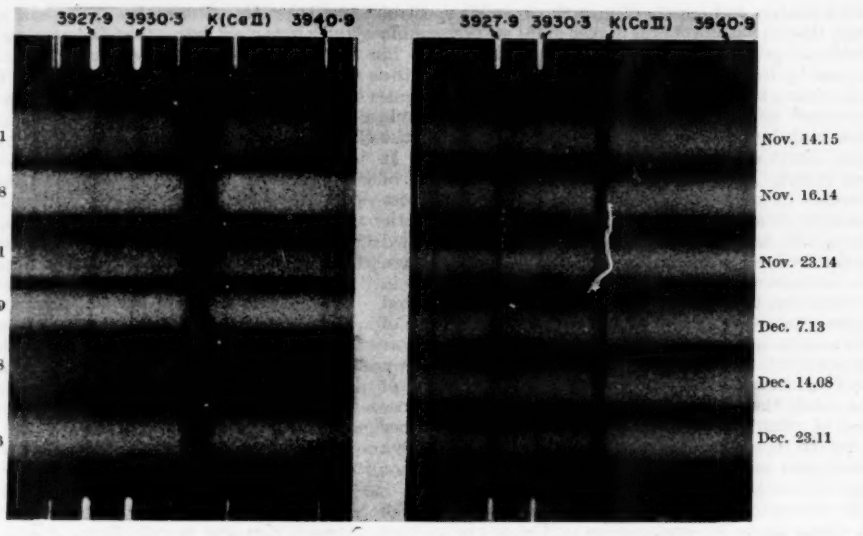
Both at Victoria and Ann Arbor good series of spectrograms were obtained, due to the full co-operation of all observers at both observatories. Detailed information on the spectrograms need not be given here. It is sufficient to state that, in general, the Victoria plates were obtained with greater resolution, a grating spectrograph giving 4·6 A./mm. being used, while the Ann Arbor plates were largely obtained with a two-prism instrument, dispersion 12·3 A./mm. at λ3933. Due consideration being given to this difference, the two sets of spectrograms give concordant results on the subject treated in this communication.

It became evident that 31 Cygni provides possibly the best opportunity yet available for the detailed study of eclipse effects; for example, the period covered by the atmospheric eclipse is greater than for ζ Aurigæ or 32 Cygni. The large amount of data secured during the 1951 eclipse will provide material for several future researches, but one observed phenomenon appears sufficiently striking and of such general interest as to warrant special mention here.

A study of the development of the *H* and *K* lines of Ca II (λλ3968 and 3933) has been made. For our purpose the *K* line is the better situated of this ultimate doublet of Ca II, since it is present as a very wide strong line in the ordinary spectrum of a cool giant star, and is not present in the spectrum of the small hot star. On the other hand, the *H* line lies in the wing of the strong hydrogen line $H\varepsilon$ (λ3970) which is present in both *K*- and *B*-type spectra. Hence one can study the development of atmospheric absorption in the *K* line against an effectively pure background of continuous radiation from the *B* star. However, it should be remarked that the structure described below occurred also in the *H* line of Ca II. A further important point is that ionized calcium extends very far out into the stellar atmosphere, and the ultimate lines are the most sensitive criterion of its presence and abundance.

It was found especially during egress that, in addition to the gradual decrease in intensity of the *K* line, a pronounced line-structure of a transitory nature appeared. In this account we deal only with the data obtained during egress; during ingress the observational coverage over the most favourable period was not as good. However, it was more than adequate to allow us to say with confidence that the occurrence of structure in the calcium lines was much more definite and lasted longer after than before total eclipse. Before totality, one day on which the *K* line showed complexity was July 16. The greater prevalence of the structure after totality is itself of interest in emphasizing the sporadic nature of the source of the effect. From about two to four weeks after the end of totality, while the *K* line was still quite wide and had a rectangular profile, subsidiary weaker absorptions appeared with varying displacements and intensities. The left column of spectra reproduced herewith shows the effect, the subordinate lines being indicated by white dots.

On October 26 there was a definite line with a Doppler shift of about 85 km./sec. to the violet of the main wide chromospheric *K* line. By October 27 this violet component had vanished, but a wing on the red side was evident which one day later had given way to a single component on the red side, displaced 110 km./sec. from the normal position. On



Spectra of 31 Cygni during 1951, showing the varying structure of the chromospheric calcium line during egress

Enlargements of selected spectrograms taken after the end of total eclipse, arranged in chronological order. The spectrograms were obtained with the grating form of the Victoria stellar spectrograph (original dispersion 4·6 A./mm.). On the left side, starting on October 26, about two weeks after the end of totality, the main chromospheric absorption line is still quite wide and strong. The positions of the weaker subsidiary components, easily seen on the original plates, are indicated by a white dot above each spectrogram. As shown on the right, by mid-November the chromospheric line had become narrow. The varying structure of the line for the next few weeks is clearly seen. In this right-hand column the narrow components are separated by amounts between 24 and 41 km./sec. This structure reminds one of the complex appearance of various interstellar calcium lines investigated with high dispersion by W. S. Adams at the Mount Wilson Observatory. Like these, it is attributed to absorption in discrete clouds of ionized calcium gas having different velocities in our line of sight, the clouds in the present case being in the extended outer atmosphere of the giant star

October 30 the displacement had increased to 130 km./sec., but had decreased next day to about 120 km./sec., and on November 1 the *K* line showed only a wing on the red side. (Recalling that these displacements correspond only to that component of velocity in the line of sight, that is, tangential to the star, the actual velocities may be considerably greater.) We see that during the six days, October 26–November 1, the satellite components of the *K* line underwent a rapid succession of changes indicating large-scale motions of singly ionized calcium atoms at high speeds and in varying directions, somewhat akin to the movement of material in the solar prominences. During this period, two to three weeks after totality, the small *B* star was travelling behind the outer regions of the lower chromosphere of the giant, and the main strong chromospheric calcium line is indicative of the main body of calcium gas in the path of the radiation. However, the continued appearance of complex structure in the *K* line gives ground for supposing that the streams they represent may actually constitute an appreciable part of the atmosphere of such stars, whereas in the solar atmosphere they are relatively minor prominences superposed on an otherwise semi-quiescent distribution of matter. On this view, the broad strong line of rectangular profile originates in a network or field of prominences that constitute the lower atmosphere of the star, the weaker satellite lines revealing only the unusually active prominences. The very low surface gravity of the giant star, relative to that of the sun, is compatible with the long life and great extent of the large-scale motions.

Between November 1 and 14 the *K* line narrowed as the *B* star shone through the increasingly tenuous outer atmosphere of the giant. On November 14 the line was definitely double; two days later the component on the red side had vanished, leaving only a weak wing. On November 23 the *K* line was again double, the undisplaced lines and those on the red side being of equal intensities. The component of shorter wave-length is referred to as the undisplaced component because the radial velocity to which it corresponds is the more constant and corresponds more closely to the velocity given by the spectral lines of the *K*-type star; also, this component decreased more uniformly in intensity than that on the red side. On December 7 and 14 the *K* line was remarkable in showing a component on the red side much more intense than the undisplaced line and some 35 km./sec. from it. The filamentary structure of the outer atmosphere of the giant star is thus apparent.

Since the *B* star moves about 2·5 solar diameters a day relative to the atmosphere of the giant component, it is clear that any line structure observed even on successive days refers to appreciably different regions of the extensive giant atmosphere. Considering, for example, the spectra obtained during October 26–November 1, we cannot be sure that on successive days we are dealing with the varying behaviour of a single prominence rather than with several different prominences. During future eclipses, spectrographic observations from terrestrial longitudes that are appropriately spaced so as to obtain a more continuous record would assist greatly in this connexion, and might provide a means of estimating the dimensions of the discrete clouds of ionized calcium.

It has been suggested recently by some astrophysicists[6], from considerations derived from studies

of the shapes and curves of growth of stellar spectral lines, that the atmospheres of cool giant stars resemble 'fields of prominences' rather than atmospheres in normal hydrostatic equilibrium. The evidence of the behaviour of the *K* line in the spectrum of 31 Cygni, discussed above, is in general agreement with this view and, indeed, may be considered as possibly the most direct evidence in its favour yet obtained. It can readily be appreciated that the application of theories of radiative equilibrium, which presuppose material stratified in parallel layers and in a static state, will have certain shortcomings when applied to the analysis of the atmospheres of such giant stars. Furthermore, while the considerable width of lines in the spectra of supergiant stars has been attributed quite reasonably to correspondingly large motions of the atoms in their atmospheres, it is perhaps unfortunate that the term 'turbulent velocity' has been used to describe the motions. The modifications of the static theories of stellar atmospheres by application of recent physical theories of turbulence proper must be open to question because the restrictive conditions under which the latter are valid do not exist in stellar atmospheres.

A hitherto anomalous feature of systems like 31 Cygni finds its explanation in the above picture of the structure of a giant stellar atmosphere. In the case of ζ Aurigæ, it has been found that for the several observed eclipses and even for ingress and egress at the same eclipse the extents of the chromosphere, as judged by spectroscopic observations, are often unequal[7]. This phenomenon can now be attributed with some confidence to prominence-like activity in the *K*-star atmosphere.

[1] *Ann. Harvard Coll. Obs.*, **28**, 93 (1898).
[2] *Lick Obs. Bull.*, **1**, 22 (1901).
[3] *Astrophys. J.*, **83**, 433 (1936).
[4] *Astrophys. J.*, **100**, 8 (1944).
[5] *Pub. Astro. Soc. Pacific*, **62**, 13 (1950).
[6] See, for example, Struve, O., *Astro. J.*, **56**, 115 (1951).
[7] See, for example, Welsh, H. L., *J. Roy. Astro. Soc. Canada*, **43**, 217 (1949); *Contrib. Dom. Astrophys. Obs., Victoria*, No. 21.

OBITUARIES

Prof. Guido Castelnuovo

Guido Castelnuovo, whose death occurred on April 27, was born in Venice on August 14, 1865, the son of a well-known high-school teacher of that city. After graduating, as a pupil of Veronese, from the nearby University of Padua, he went, in 1888, to Turin, where Corrado Segre was already installed as professor. The effects of this encounter were immediate and striking; for the conversations which the two young geometers held during their walks about the city resulted in the completion of the classical theory of algebraic curves, characterized by the frequent use of hyperspatial methods which is the hall-mark of the Italian school.

In 1891 Castelnuovo was appointed to the chair of geometry in Rome; here he was soon joined by Federigo Enriques, who had just left Pisa, and who had arrived armed with the intention of founding the new science of algebraic surfaces on a basis analogous to that previously adopted by Segre for curves. Castelnuovo quickly perceived the best means of instructing the younger man: the peripatetic conversations were resumed, this time on a grander scale. (It may be added that Enriques eventually followed the same method with his own pupils.) Mutual stimulus again had its advantages; and there now began a collaboration and friendship (strengthened later by Castelnuovo's marriage to Enriques's sister) which led to the creation of the invariantive theory of surfaces, in its essentials almost entirely their work.

The partnership was in all respects an ideal one: while Enriques, an impulsive intuitionist, was held in check by his friend's temperamental caution, on the other hand, Castelnuovo's reluctance to publish was often overcome by encouragement. Although the number of avowedly joint publications was small (but highly significant), the reciprocal influence on their work must have been incalculable. When, in 1894, Enriques went to Bologna, the exchange of ideas was maintained by an almost daily correspondence which lasted for many years. The story of the collaboration, if fully told, would form one of the most fascinating, as it is certainly one of the greatest, episodes in mathematical history.

In 1935 Castelnuovo reached the age of retirement; to mark the occasion, his friends and disciples organized a ceremony in his honour, and initiated the publication of his selected papers (see *Nature* of December 10, 1938). Castelnuovo's seniority thus spared him the worst effects of the racial laws of 1938; but he suffered a grievous blow when, a year later, the Lincei Academy, to which he had been elected in 1901, was virtually dissolved.

With the fall of the Fascist regime, one of the first acts of the new government was to re-establish the Academy; this could not be fully accomplished until 1946 and then, inevitably, Castelnuovo was the choice for president. In 1949 the Italian Government, in recognition of his services, nominated him a life senator of the Republic. He continued with remarkable energy and resourcefulness to perform his various duties until a few months before his death.

It is difficult for a mathematician to imagine Rome without Castelnuovo; during his sixty years sojourn there, he had become one of the city's principal monuments, revered and loved as much as any of them. With his nobility of character and utter integrity of conduct, he set a standard for the nation and for all mankind. As a lecturer, even in his last years he was unique: the measured utterance, the unbroken succession of perfectly turned phrases, free from all suggestion of rhetoric, was something never to be forgotten. While it is perhaps impossible for such a man to be wholly unconscious of his superiority, Castelnuovo gave no sign of it beyond a certain Olympian serenity tempered, however, with great kindliness towards all. In the course of his career through the high noon and—as he held—into the sunset of modern mathematics, he received many academic distinctions; in particular he had been an honorary member of the London Mathematical Society since 1907. But it was typical of the man that, when replying to the speeches made at his retirement ceremony, he should have remarked: "For myself, I have always preferred the joys of family life to the glories of scientific achievement". That may well be his most fitting epitaph.

L. Roth

Dr. Maria Montessori

The death on May 6 of Madame Montessori at the age of eighty-one removes a remarkable figure in twentieth-century education. Entering the Medical Faculty of the University of Rome, she was the

first Italian woman to obtain the degree of M.D. Her first notable work was with mental defectives, with whom she used methods based on those of Séguin. With some of the children classified as mental defectives she obtained results which were acclaimed as remarkable, some of her children doing better than the (supposed) normal children in the State examination.

We know now, however, how unreliable the detection of mental deficiency was in those days—and even to-day by inadequately trained psychologists or medical men. Probably some of Dr. Montessori's mental defectives were appreciably above the borderline in intelligence, and some of the supposed 'normal' below.

Shortly afterwards, Dr. Montessori began to apply her ideas to normal children, maintaining that methods good for mentally deficient children were appropriate for very young children. Her originality consisted chiefly in two things: first, her elaborate apparatus for 'sense-training', which was self-checking so that the child found out his errors without correction; and second, in her doctrine that the child should be free to choose his activities. Her main influence, however, was through her charm of personality, her intense love of little children, and her unbounding enthusiasm for reform—social or educational—which would benefit them.

Her first and best book, "The Montessori Method", attempts a justification of her views about sense-training, but with serious psychological fallacies. No doubt substantial gains in knowledge of shapes and colours and in hand control came as a result of play with the apparatus; but the main truth behind Dr. Montessori's practice was that it is better for dull and very young children to play about for a time with things of slight or even of no educational value, rather than to be prematurely forced, as they usually were in those days, to begin reading and arithmetic when quite unable to make any progress, and so develop an antagonism to such work and become hopeless about their own abilities.

The common idea that Montessori advocated complete freedom for the children is quite wrong. She states that "it is necessary to hinder . . . with absolute rigour . . . and little by little suppress, all those things which we must not do". She was also right, however, in maintaining that to provide the child with work precisely adapted to his stage of development, is to make much repressive discipline in the school unnecessary. C. W. VALENTINE

Dr. W. R. Ivimey Cook

DR. IVIMEY COOK, whose recent death at the age of fifty, after a short illness, will be deeply regretted by his wide circle of friends, was senior lecturer in botany at University College, Cardiff. He was educated at Dulwich College and later at King's College, University of London, where he took his Ph.D. degree, and for some time acted as demonstrator. Afterwards he was appointed assistant lecturer at the University of Bristol, where he remained for four and a half years, eventually transferring to University College, Cardiff.

Dr. Cook was, of course, primarily a mycologist, and his work on Archimycetes and especially on the Plasmodiophorales was widely known and appreciated. While at Cardiff he organized a considerable series of researches, in collaboration with pupils, on the Phycomycetes, which added greatly to our knowledge of the group in Britain. These he intended to publish as a collected work; but post-war costs forced postponement of the plan.

His name was familiar to several generations of medical students as co-author, with Dr. Hentschel, of "Biology for Medical Students", a very successful text-book, now in its fourth edition. He was also co-author of "Plant Science Formulæ" and "Practical Field Ecology", and was collaborating in the production of two large general text-books, on theoretical and practical botany respectively; but at the time of his death only one of these volumes had appeared. He was also planning and had almost finished a book on economic botany in which he was deeply interested.

Dr. Cook was a man of indefatigable energy and wide interests, and he was one of the hardest workers I have ever known. No man ever threw himself more unselfishly into his work, and the Department of Botany at Cardiff owes him a great debt for the many developments he carried through. A fact not generally known is that he was one of the first to give the impetus to the scheme for the national training of laboratory technicians, which has recently come to fruition. During the War he served as a special constable and also found time to run a small-holding, on which he raised almost every kind of livestock, all without any relaxation of his professional duties. Home and garden, camping and canoeing were his pleasures and contributed much to a life lived to the full.

His cheerful, friendly presence, his very human love of discussion and his remarkable flair for organization will long be missed in his College and wherever botanists are forgathered.

R. C. MCLEAN

Dr. F. Earnshaw

DR. FREDERICK EARNSHAW, who died in Edinburgh on April 27, was born in 1914. He was a student at the University of Cambridge during 1933–37. In 1937 he was appointed assistant lecturer in botany at the Edinburgh and East of Scotland College of Agriculture, relinquishing the post on joining the Army in 1940. During the period 1937–40 he also worked as a research student at the Scottish Plant Breeding Station and prepared a thesis entitled "Genetical and Cytological Studies in the Genus *Plantago*" which gained him the degree of Ph.D. at the University of Edinburgh.

After returning from the Army in 1946, Earnshaw joined the staff of the National Institute of Agricultural Botany, Cambridge, as an economic botanist, and while there conducted work on varietal differences in cereals.

In 1949 a new post of genecologist having been established at the Scottish Plant Breeding Station, Earnshaw left Cambridge and returned to Edinburgh to revive a programme of genetical ecological investigations which had been interrupted during the War. He is survived by his wife, two sons and a daughter.

WE regret to announce the following deaths:

Dr. F. W. Carter, F.R.S., lately consulting engineer to the British Thomson-Houston Co., Ltd., on May 29, aged eighty-one.

Colonel L. Newcombe, C.B.E., librarian and secretary to the Trustees, National Central Library, during 1926–44, on May 25, aged seventy-two.

NEWS and VIEWS

Queen's Birthday Honours List

THE following names of scientific men and others associated with scientific work and interests appear in the Queen's Birthday Honours List.

Baronet: Sir Cecil Wakeley, president of the Royal College of Surgeons.

Knights: D. Emrys Evans, principal of the University College of North Wales, Bangor; W. S. Farren, technical director, A. V. Roe and Co., Ltd.; Prof. R. A. Fisher, Arthur Balfour professor of genetics, University of Cambridge; Dr. W. E. Hume, emeritus professor of medicine, University of Durham; Dr. B. A. Keen, director of the East African Agriculture and Forestry Research Organization; Prof. B. H. C. Matthews, professor of physiology in the University of Cambridge, for services to the Air Ministry; Dr. R. E. M. Wheeler, secretary of the British Academy and professor of the archæology of the Roman Provinces, University of London; Dr. T. W. J. Taylor, principal of the University College of the West Indies.

K.B.E.: Edward Hale, secretary of the University Grants Committee.

C.B.: Capt. C. R. P. Diver, director-general of the Nature Conservancy.

C.M.G.: Dr. C. Wilcocks, director of the Bureau of Hygiene and Tropical Diseases, London.

C.B.E.: E. C. Bowyer, director of the Society of British Aircraft Constructors; Dr. T. J. Drakeley, principal of the Northern Polytechnic, London; Colonel W. R. MacF. Drew, lately professor of medicine, Royal Medical College, Baghdad; J. P. Edwards, director of forestry, Federation of Malaya; Prof. E. R. Hudson, director of the Canterbury Agricultural College, New Zealand, for services to agriculture; Miss G. E. M. Jebb, lately principal of Bedford College for Women, University of London; M. B. Knowles, principal actuary, Government Actuary's Department; A. P. Long, director of forestry for Wales, Forestry Commission; N. G. McCulloch, chairman of council, British Cotton Industry Research Association; W. A. C. Newman, chemist and assayer, Royal Mint; Prof. J. Proudman, professor of oceanography, University of Liverpool; W. J. Richards, chief superintendent, Telecommunications Research Establishment, Ministry of Supply; Dr. R. L. Smith-Rose, director of radio research, Department of Scientific and Industrial Research; H. Sutton, director of materials research and development (air), Ministry of Supply; Prof. L. M. Milne-Thomson, professor of mathematics, Royal Naval College, Greenwich; S. S. Tindall, acting development commissioner, Uganda; Dr. D. T. A. Townend, director-general of the British Coal Utilisation Research Association; L. J. Wild, pro-chancellor of the University of New Zealand, for services to education and agriculture.

I.S.O.: Miss E. A. Leighton, chief executive officer, Department of Scientific and Industrial Research; O. B. Miller, forest officer, Bechuanaland Protectorate; Captain H. V. M. Metivier, lately deputy director of agriculture (animal husbandry), Trinidad; H. A. Mullett, director and permanent head of the Department of Agriculture, State of Victoria.

Archæology at Cambridge: Prof. D. A. E. Garrod

PROF. DOROTHY GARROD has decided to resign from the Disney professorship of archæology in the University of Cambridge as from September 30 next so as to devote herself to the important excavation work in western France which she has been undertaking in her spare time during the past few years, and in future she will normally be in residence in France. Prof. Garrod was appointed to the Disney chair in 1939, but spent much of the War period analysing air photographs for the R.A.F. The post-war years have been a time of expansion and consolidation in the Department. Tripos regulations have been recast, and the increasing number of students taking the archæological options in the examinations is now catered for in a much more satisfactory manner. Prof. Garrod has taken a prominent part in effecting these changes, and she leaves the 'school' in a very flourishing state. All members of the Department regret her decision to resign several years before the retiring age, while recognizing the archæological importance of the work to which she intends to devote herself. Prof. Garrod's book "The Upper Palæolithic Age in Britain" is well known, as, too, is her monumental work on the prehistory of a number of cave sites in Mount Carmel. The excavations now in hand, though perhaps not on so ambitious a scale as those in Palestine, promise to be both interesting and important. The good wishes of all her friends will go with Prof. Garrod to her new French home.

Dr. J. G. D. Clark

DR. GRAHAME CLARK, who succeeds Prof. Garrod, is a graduate of the Cambridge 'school' and is at present lecturer there. His interest in the Stone Age started while at Marlborough College; all over the Downs the relics of early man abound, and as a schoolboy he became fired with a passion to know more about his remote ancestors. At Cambridge he took the Archæological and Anthropological Tripos with brilliant results. His first book, "The Mesolithic Age in Britain", was a very useful compilation; but it was in the next, "The Mesolithic Settlement of Northern Europe", that he really showed his capabilities. Since then, many more works have come from his pen. Some of them are more designed for the general reader, such as "Prehistoric England" in the Batsford series. Recently, in a volume entitled "Prehistoric Europe", Dr. Clark has developed a new view on prehistoric times in Europe which promises to be exceedingly fruitful. For the past few years he has been conducting spectacular excavations at Star Carr, near Scarborough, which have revolutionized our knowledge of the Mesolithic settlement in north-eastern England. Dr. Clark has also travelled extensively in Scandinavia and Germany. He was elected a Fellow of the British Academy in 1951. He is a Fellow of Peterhouse.

Mathematics at Queen Mary College, London

PROF. G. C. MCVITTIE is resigning from the chair of mathematics in Queen Mary College, London, to which he was appointed in 1948 (see *Nature*, **162**, 56; 1948), and is taking up the post of professor of astronomy and head of department in the University of Illinois.

Prof. V. C. A. Ferraro

Prof. V. C. A. Ferraro, who succeeds Prof. McVittie, is a graduate of the Imperial College of Science and Technology, London, and took his Ph.D. there in 1930. He was then a demonstrator in mathematics in the College for three years, until his appointment as assistant lecturer, and later (from 1937) as lecturer, at King's College, London. Prof. Ferraro was appointed in 1947 to the newly created chair of applied mathematics in the University College of the South-West of England, Exeter. In 1948 he spent some months on leave from his university duties as a guest investigator at the Department of Terrestrial Magnetism of the Carnegie Institution of Washington, and in the succeeding year he was invited to deliver a course of lectures on solar and cosmical magnetism at the Royal Observatory of Belgium. Prof. Ferraro is probably best known for his work in conjunction with Prof. S. Chapman on the theory of magnetic storms and the aurora. Their researches on this very intricate subject began in 1927 and have continued intermittently to date; their contributions to this subject seem to be gaining much general acceptance, though there is a great scope for further development, and in many respects the subject remains obscure and controversial. Prof. Ferraro has also made several important contributions to the theory of solar magnetism (one of his most interesting theorems relates to the non-uniform rotation of a star possessing a general magnetic field), and to general electromagnetism and the theory of diffusion in the ionosphere. Besides his scientific work, he has strong artistic leanings, being accomplished both in pictorial art and as a singer.

Royal Charter for the School of Pharmacy, University of London

The granting of a Royal Charter of Incorporation to the School of Pharmacy of the University of London is a tribute to an institution which has played a most important part in the development of pharmaceutical and medical science, and has had a great and lasting influence on pharmaceutical practice, not only in Great Britain but also abroad. The Charter also marks the end of a venture started by the Pharmaceutical Society in 1842 in pursuance of its ambition to promote a uniform system of education in pharmacy and to place the practice on a professional basis. For more than a hundred years the School has been the child of the Pharmaceutical Society and financed from the resources of the pharmaceutical profession. In 1948, however, the School was given an independent existence, its finance being provided by university grants. Its new Council has a wide representation, consisting of the Dean and teachers, nominees of the University of London and of the Pharmaceutical Society, together with co-opted members from industry and research. Medicine is represented by Sir Archibald Gray, Sir Henry Dale and Dr. Charles Harris, with Sir Harry Jephcott as the chairman of the Council. It seems now a far cry to the early days of the School of Redwood, Attfield and Crossley in chemistry, Jonathan Pereira in materia medica, Greenish in pharmacy and Thomson, Bentley and Reynolds Green in botany. These men laid a firm foundation for the rapid changes that were to come as pharmacy expanded from retail into hospitals and manufacturing laboratories. The General Medical Council has consistently acknowledged the debt owed to them and their successors in the School in the compilation of all the editions of the British Pharmacopœia. The School has pioneered many new developments and has added pharmacology and microbiology to its basic sciences, in order to cope with the biological standardization of drugs, chemotherapy and the increasing importance of the provision of sterile medicaments and materials for parenteral injection. The Royal Charter now confirms the School in its position of responsibility as a School of the University of London, and those who are familiar with its history will feel a satisfaction that good provision has been made to continue its work.

Oil-processing of 'Tough' Rubbers

The seventh Foundation Lecture of the Institution of Rubber Industry was given in the Civic Hall, Wolverhampton, on May 23 by Dr. R. P. Dinsmore, vice-president in charge of research and development of the Goodyear Tire and Rubber Co., Akron, U.S.A., who chose as his subject the "Economic and Physical Aspects of *GR-S* Modifications". Dr. Dinsmore discussed a new technique whereby 'tough' rubbers may be processed in factories using conventional equipment designed for the ordinary soft rubbers, often known as 'cold' or *GR-S* rubbers. Large quantities of petroleum oil are added to the 'tough' rubbers, and this acts as an internal lubricant so that the tendency of the rubber to crack and tear under tensions, as in the shaping of tyre treads, is avoided. On an average, about 125 lb. of this oil-masterbatched rubber, as it is called, can be produced for the same cost of 100 lb. of conventional cold rubber and the cost of the oils; carbon black can be added to improve the quality of the rubber. Various plasticizing liquids have been used, the most successful so far being one part of petroleum oil to four parts of butadiene-styrene. Tyre-tread tests have shown that oil-masterbatched rubbers give up to 21 per cent longer tread-wear than *GR-S* rubber, and that their lower heat build-up gives promise for use in heavy-duty truck tyres. The oil-masterbatch process has been developed in the Goodyear Company's research laboratories under the sponsorship of the Synthetic Rubber Division of the Reconstruction Finance Corporation, and commercial production started about a year ago in a synthetic-rubber plant at Houston, Texas, and also in factories operated by other firms. Recent experiments with this oil-processing technique give great promise for the new tough synthetic 'Alfin' rubber, developed by Prof. A. A. Morton, of the Massachusetts Institute of Technology; this rubber has been described as the most resilient of all the polymers of high molecular weight and is extremely difficult to process under ordinary conditions. In the 'Alfin' process the monomer is usually polymerized in a hydrocarbon solvent such as pentane to an extremely high molecular weight. Processing oils are then added and thoroughly incorporated before evaporation of the solvent. In this way, one, or even two, parts of oil can be added to one part of polymer to give an oil-masterbatch which processes much more easily than the very tough raw polymer. Another method is to add the oil to the monomer as a partial or total replacement for the solvent prior to polymerization.

Physical Society

At the annual general meeting of the Physical Society, held in London on May 20, the following officers were elected: *President*, Prof. R. Whidding-

ton; *Vice-Presidents who have filled the office of President*, Prof. C. H. Lees, Sir Frank Smith, Sir Owen Richardson, Dr. W. H. Eccles, Prof. A. O. Rankine, T. Smith, Sir Charles Darwin, Prof. E. N. da C. Andrade, Sir David Brunt, Prof. G. I. Finch, Prof. S. Chapman and Prof. L. F. Bates; *Vice-Presidents*, Dr. D. Roaf, Dr. A. C. G. Menzies, J. H. Awbery and Dr. R. C. Evans; *Honorary Secretaries*, C. G. Wynne and Dr. H. H. Hopkins; *Honorary Librarian*, Dr. R. W. B. Pearse; *Honorary Foreign Secretary*, Prof. E. N. da C. Andrade; *Honorary Treasurer*, A. J. Philpot; *New Members of Council*, Prof. R. W. Ditchburn, Dr. E. P. George, Dr. H. G. Kuhn and A. G. Peacock.

Illuminating Engineering Society: Officers for 1952–53

At the annual general meeting of the Illuminating Engineering Society held at Eastbourne on May 22, the following officers and new members of Council were elected: *President*, Dr. W. J. Wellwood Ferguson; *Vice-Presidents*, A. G. Higgins, E. C. Lennox, Alan H. Owen, J. F. Stanley and W. J. P. Watson; *Honorary Treasurer*, W. J. Jones; *Honorary Secretary*, H. C. Weston (32 Victoria Street, London, S.W.1); *Honorary Editor*, Dr. W. E. Harper; *New Members of Council*, A. D. S. Atkinson, F. M. Hale, Dr. R. G. Hopkinson, R. A. Lovell, J. S. McCulloch, W. T. F. Souter, W. R. Stevens and D. L. Tabraham.

University of Birmingham: Appointments

The title of reader in endocrinology has been conferred by the University of Birmingham on Dr. P. L. Krohn, lecturer in anatomy. The following have been appointed lecturers in the University: Dr. D. Mary Jackson (physiology), Dr. A. S. Jones (chemistry), J. Llewellyn (zoology), H. Rees (genetics), T. K. Ross and R. B. Shearn (chemical engineering), M. B. Stedman (geography) and I. Strachan (geology). The following have been appointed research fellows: A. Todrick and M. Piercy (neurological studies). The title of University research fellow has been conferred upon the following for the duration of their present appointments: L. Kerr, Royal Society Warren research scholar (electron physics), Dr. F. Shafizadeh (chemistry), Dr. J. G. Lawson and Dr. V. T. Brooks (mining), and Dr. D. Hamer and Miss D. M. Waldron (cancer research). Mr. L. Kuper has resigned from his post as lecturer in sociology in the University on appointment as professor of social science in the University of Natal.

Announcements

Honorary degrees of the University of Cambridge have been conferred on the following, among others: Mr. R. A. Butler, Chancellor of the Exchequer, and Hon. Fellow of Pembroke and of Corpus Christi Colleges; Sir Edward Bailey, director during 1937–45 of the Geological Survey of Great Britain; Dr. K. T. Compton, president during 1930–48 of the Massachusetts Institute of Technology; Mr. O. G. S. Crawford, archæology officer of the Ordnance Survey during 1920–46; Sir Gordon Gordon-Taylor, the distinguished surgeon and past president of the Royal Society of Medicine.

Dr. R. A. E. Galley, who has for the past year been seconded from the Agricultural Research Council to the Office of the Lord President of the Council, secretariat of the Advisory Council on Scientific Policy, has been appointed, as from January 1, 1953, to be director of Colonial Products Research with the rank of deputy chief scientific officer, in succession to Sir John Simonsen, who is retiring. Dr. Galley will also take over responsibility for the work of the Colonial Products Advisory Bureau. Dr. J. R. Furlong, the present principal of the Bureau, who was due to retire at the end of this year, has agreed to remain in the Service for a further year as deputy director of Colonial Products Research.

A new Fatigue Testing Laboratory of the British Welding Research Association (29 Park Crescent, London, W.1) will be officially opened at Abington Hall, Abington, near Cambridge, on June 23, by the Right Hon. Lord Woolton, Lord President of the Council.

The first award of the English Electric research fellowship in aeronautics, which was recently established by the English Electric Company, Ltd., at the College of Aeronautics, Cranfield, has been made to Mr. G. C. C. Smith, a graduate in mechanical engineering of the University of Birmingham who is now in his final year of the postgraduate diploma course at the College of Aeronautics. The fellowship, which is worth £500 and is tenable for one year, is designed to promote studies in aeronautical engineering, with particular reference to the problems of vibration, stability and control of aircraft. Mr. Smith will undertake a structural research project during his tenure of the fellowship.

The summer meeting and annual general meeting of the Society for Applied Bacteriology will be held in Cambridge during July 21–24. The programme will consist of sessions devoted to the reading of papers, local visits of interest, and a symposium on July 24 on "Aspects of Food Preservation". Further information can be obtained from the honorary secretary of the Society, G. Sykes, Boots Pure Drug Co., Ltd., Microbiology Division, Standards Department, Nottingham.

The Printing, Packaging and Allied Trades Research Association is holding a conference and exhibition at the Technical College, Shakespeare Street, Nottingham, during June 16–17, which will be repeated at the Assembly Room, Chamber of Commerce, New Street, Birmingham, during June 19–20. The conference will consist of three sessions, the first, a private one, being on "Research and the Printer", and the other two, open to the public, being on "Technical Progress" and a "Brains Trust", respectively. Further information can be obtained from the Association at Patra House, Randalls Road, Leatherhead, Surrey.

A summer school in programme design for automatic digital computing machines, on the same lines as those of previous years, will be held in the University Mathematical Laboratory, Cambridge, during September 16–26. The course will give a basic training in the mathematical use of machines, dealing with the processes employed and their embodiment in programmes which specify the operation in detail. Lectures and practical classes will be held in the design of programmes for the Laboratory's electronic delay storage automatic calculator. Application forms, to be completed by July 14, can be obtained from G. F. Hickson, secretary of the Board of Extra-Mural Studies, Stuart House, Cambridge.

ROTATION-VIBRATION SPECTRA AND STRUCTURE OF SIMPLE POLYATOMIC MOLECULES*

By Dr. G. HERZBERG, F.R.S.
Division of Physics, National Research Council of Canada, Ottawa

PRECISE quantitative information about the geometrical structure of simple polyatomic molecules, about their moments of inertia, internuclear distances, and valence angles can be obtained by a study of their rotation and their rotation-vibration spectra. The rotation spectra lie in the microwave region, and the rapid development of this field during the past few years has greatly added to our knowledge of molecular structure. Nevertheless, the study of rotation-vibration spectra by more conventional methods is not made superfluous by these modern developments, particularly since molecules without dipole moment do not exhibit a microwave absorption spectrum, and since in addition the rotation-vibration spectrum allows one to investigate the effect of vibration on the rotational constants. It is necessary to know this effect if the influence of zero-point vibration is to be eliminated in the determination of internuclear distances. In addition, this variation of the rotational constants must be known if accurate thermodynamic functions are to be calculated.

The fine structure of rotation-vibration spectra can be studied in the ordinary infra-red, where the fundamentals and low overtone and combination bands are located, or in the photographic infra-red where higher overtone and combination bands may be found. Until the recent development of the photoconductive infra-red detectors (lead sulphide, lead selenide and lead telluride), much higher resolution was obtainable in the photographic infra-red than in the ordinary infra-red. However, for work in the former region, very long absorbing paths are required in order to get sufficient absorption. By the method of J. U. White[1,2], paths up to 2,000 m. are now fairly readily available. Most of the work described in the following is based on photographic infra-red spectra.

The rotational levels of linear polyatomic molecules are entirely similar to those of diatomic molecules. The rotational term values $F_v(J)$ are given by

$$F_v(J) = B_v J(J+1) - D_v J^2(J+1)^2 + \ldots, \quad (1)$$

where

$$B_v = B_e - \sum_i \alpha_i(v_i+\tfrac{1}{2}) \text{ and } B_e = \frac{h}{8\pi^2 c I_e}. \quad (2)$$

Here B_e is the rotational constant for the equilibrium position which, apart from a constant, is the reciprocal of the moment of inertia I_e in the equilibrium position. J is the rotational quantum number which represents the total angular momentum of the molecule in units $h/2\pi$. The α_i are constants, small compared to B_e, which determine the dependence of B on the different vibrations. D_v is very small compared to B_v and represents the influence of centrifugal stretching. For the purposes of this article it will be disregarded. Fig. 1*a* shows a diagram of the rotational levels represented by equation (1).

If perpendicular vibrations are excited, a vibrational angular momentum about the symmetry axis in general arises. Depending on whether this angular momentum is 0, 1, 2, . . . $\times h/2\pi$, we distinguish

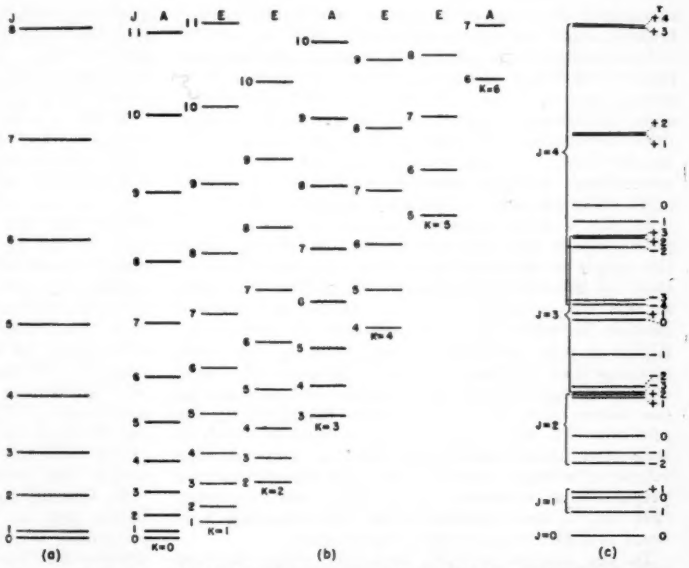


Fig. 1. Rotational levels of (*a*) linear, (*b*) symmetric top, and (*c*) asymmetric top molecules

$\Sigma, \Pi, \Delta, \ldots$ vibrational levels similar to the Σ, Π, Δ electronic states of diatomic molecules.

The most important types of transitions are Σ—Σ, Π—Σ and Π—Π, which are in all respects similar to the corresponding electronic transitions of diatomic molecules. Σ—Σ bands have simple P and R branches (corresponding to $\Delta J = -1$ and $+1$) with one line missing between the two (the zero gap), while Π—Σ and Π—Π bands have in addition a Q branch (corresponding to $\Delta J = 0$) starting near the band origin. This Q branch is strong for Π—Σ, but weak for Π—Π bands.

For molecules with a centre of symmetry, alternate rotational levels are symmetric and antisymmetric with respect to an exchange of the identical nuclei, and in consequence there is an alternation in the intensities of successive lines (or alternate lines are

* Substance of a series of three special University lectures held during January–February in King's College, London.

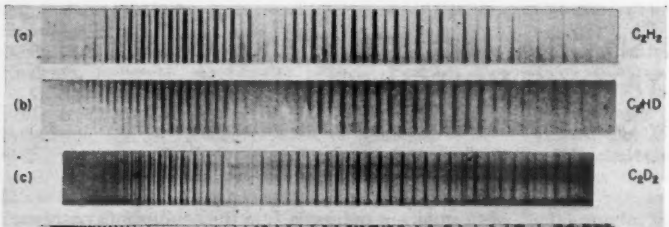


Fig. 2. Σ—Σ bands of linear molecules. (*a*) 10,370 A. band of C_2H_2, (*b*) 10,950 A. band of C_2HD, (*c*) 8700 A. band of C_2D_2, (*d*) 11,140 A. band of N_2O, (*e*) 12,200 A. and 12,270 A. bands of CO_2, (*f*) 10,320 A. band of diacetylene. The wave-lengths given refer to the band centres. The individual spectra are on different scales

missing if the nuclear spins are zero) just as for homonuclear diatomic molecules.

Conversely, when such simple bands, particularly those with *P* and *R* branches only, are observed, it follows that the molecule concerned is linear; and when an intensity alternation (or alternate missing lines) is observed, it follows that the molecule is symmetrical. These conclusions can be drawn immediately from the appearance of the bands under high resolution without detailed measurement.

In Fig. 2 a few examples of Σ—Σ bands in the photographic infra-red are given. In all six cases the simple structure of the bands shows immediately that the molecules are linear. While this has been known for acetylene, nitrous oxide and carbon dioxide for many years, in the case of diacetylene (C_4H_2) it was not known with certainty until the recent work of Vallance Jones[3] at Ottawa. The band of diacetylene in Fig. 2*f* is perhaps not as clear as one might hope, but this is readily explained by the presence of a 'hot' band, that is, a band in which in both the upper and lower state a perpendicular vibration is singly excited. Since for diacetylene one perpendicular vibration has a rather low frequency (231 cm.$^{-1}$), the intensity of the corresponding 'hot' band is high even at room temperature.

In the spectra of C_2H_2 and C_2D_2 (Figs. 2*a* and 2*c*), there is a clear intensity alternation showing that the acetylene molecule has a centre of symmetry, while for C_2HD no intensity alternation is present, in agreement with expectation. It may be noted that in C_2H_2 the lines with odd *J*, and in C_2D_2 those with even *J*, are the strong ones, in conformity with the fact that protons follow Fermi statistics and deuterons follow Bose statistics. The absence of an intensity alternation in the N_2O band (Fig. 2*d*) shows conclusively that N_2O does not have the symmetrical structure N—O—N but the structure N—N—O, as was first shown from far infra-red bands by Plyler and Barker[4]. In the case of CO_2 there is no intensity alternation, but alternate lines are missing, as can be seen from the fact that the lines of the *R* branch fall half-way between the lines one would have expected by extrapolating the *P* branch on the assumption of no alternate missing lines. Therefore, it follows that CO_2 has the symmetrical structure O—C—O. In the case of diacetylene, again, an intensity alternation is present, even though it is not very clear without more detailed measurements because of the overlapping hot band. The lines visible in the reproduction (Fig. 2*f*) are, in fact, the strong lines, the weak lines (of one-third intensity) being too faint to come out. Thus diacetylene does have the symmetrical structure H—C≡C—C≡C—H as expected from chemical arguments.

In Fig. 3 is shown, as an example of a Π—Σ band, a spectrogram of the HCN band at 10,800 A., which shows clearly the strong *Q* branch which arises in addition to *P* and *R* branches in this case.

In the case of the CO_2 band of Fig. 2*d*, and very faintly also for the C_2H_2 and C_2D_2 bands, a hot band of the Π—Π type can be recognized. Π—Π bands consist of two sets of almost coinciding (and usually unresolved) *P*, *Q* and *R* branches, and for symmetrical molecules the intensity alternation in these two sets is opposite so that no intensity alternation (or alternate missing lines) is apparent. Thus for CO_2 the spacing of the lines of the hot band (at the right in Fig. 2*e*) is roughly half that of the main band. The faint *Q* branch is overlapped by the stronger lines of the main band. The fragments of the faint hot bands of C_2H_2 and C_2D_2 in Figs. 2*a* and 2*c* also show no intensity alternation.

By careful measurement of the individual lines of bands such as those shown in Figs. 2 and 3, the rotational constants B_v and D_v in the upper and lower states can be evaluated. Usually this is done by means of combination differences or combination sums[5]. The most important B_v value is, of course, B_0, the rotational constant of the lowest vibrational level. Only if a sufficient number of different B_v values have been determined, and all the α_i in (2) have been obtained, is it possible to determine B_e the

Table 1. Rotational Constants, Moments of Inertia, and Internuclear Distances of Linear Molecules obtained from Rotation-Vibration Spectra

	B_0 (cm.$^{-1}$)	B_e (cm.$^{-1}$)	I_0 (10^{-40} gm. cm.^{2})	I_e (10^{-40} gm. cm.^{2})	r_0 and r_e (10^{-8} cm.)
CO_2	0·3904$_3$	0·3920	71·67$_2$	71·39	r_0 (C—O) = 1·161$_2$, r_e (C—O) = 1·159$_2$
N_2O	0·4191$_2$	0·4214$_5$	66·76$_5$	66·39$_7$	r_0 (N—N) = 1·12$_8$*, r_e (N—O) = 1·19$_1$*
HCN	1·47815	1·4846	18·931$_1$	18·849	r_0 (C—H) = 1·059
DCN	1·2088		23·149		r_0 (C≡N) = 1·157
C_2H_2	1·1769$_2$	1·1838	23·776 (*a*)	23·638 (*a*)	from (*a*) r_0 (C—H) = 1·059, r_0 (C≡C) = 1·207
C_2HD	0·9914$_1$	0·9967	28·225 (*b*)	28·076 (*b*)	and (*b*) r_0 (C—H) = 1·060, r_0 (C≡C) = 1·203
C_2D_2	0·8478$_7$	0·8507$_5$	33·004 (*c*)	32·892 (*c*)	from (*a*) r_0 (C—H) = 1·058, r_0 (C≡C) = 1·208
					and (*c*) r_0 (C—H) = 1·064, r_0 (C≡C) = 1·201
C_4H_2	0·1464$_1$		191·1$_2$		r_0 (C—C) = 1·37$_4$

* From microwave data

rotational constant that refers to the equilibrium position. In Table 1 the B_0 and B_e values, and the corresponding moments of inertia I_0 and I_e obtained from rotation-vibration spectra of linear molecules, are listed.

In the case of hydrogen cyanide and nitrous oxide the following B_0 values have been obtained from the microwave spectrum[6,7]: $B_0(HCN) = 1{\cdot}47779_7$ cm.$^{-1}$ and $B_0(N_2O) = 0{\cdot}41903409$ cm.$^{-1}$. (In determining these values from the microwave spectrum, the values of D_0 from the infra-red spectrum have been used. Here and in the tables the conversion factors of G. Herzberg, "Spectra of Diatomic Molecules" (New York: Van Nostrand Co., 1950) have been used.) While the latter value agrees very well with the infra-red value of Table 1, for hydrogen cyanide there is a discrepancy well outside the limits of both determinations. The infra-red value (Table 1) is based on a large number of different combination differences, while only one microwave line has been found so far. (*Note added in proof.* Since this was written, both the Duke University and the Columbia University groups have re-investigated the microwave spectrum of HCN (to be published shortly). The previous micro-wave value given above was erroneous. The new value, $1{\cdot}47830_3$, is in excellent agreement with the infra-red value of Douglas and Sharma[17] given in Table 1.)

In the case of carbon dioxide the moment of inertia determined from the spectrum supplies directly the carbon–oxygen distance in the equilibrium position. It is given in the last column of Table 1. For all the other molecules under discussion, since there are two or more unknown internuclear distances, one moment of inertia is not sufficient. However, since in isotopic molecules the equilibrium internuclear distances are the same, they can be determined by using the moments of inertia of as many isotopic molecules as there are unknowns. Thus, from the B_e (and I_e) values of C_2H_2 and C_2HD, the r_e values given in the last column of Table 1 were obtained many years ago[8]. Recently, a check was obtained by combining the B_e (and I_e) values of C_2H_2 with those[9] of C_2D_2. As seen from Table 1, the agreement is very satisfactory. In addition to the r_e values, r_0 values are also given which were obtained from the B_0 values; that is, it was assumed that the r_0 values are the same in isotopic molecules (which, on account of the zero-point vibration, is certainly not rigorously true). For all other cases, for lack of adequate data, only B_0 values have been obtained, and one is dependent on the assumption of equal r_0 values in isotopic molecules to obtain approximate internuclear distances. It is seen from Table 1 that for acetylene the error committed by using B_0 values is not large, but it does lead to such anomalies as the fact that r_0(C—H) turns out to be slightly smaller than r_e(C—H), when the reverse would be expected. This emphasizes the fact that the r_0 values thus obtained are effective values of a rather special kind, and not simply average values of r in the lowest vibrational level. The r_0 values given in Table 1 for hydrogen cyanide and nitrous oxide are of this type. In the case of diacetylene, no isotopic molecules have as yet been investigated. However, assuming the C—H and C≡C distances to be the same as in acetylene, an assumption that would be expected to hold at least in a fairly good approximation, one obtains for the C—C single-bond distance the value given in the last column of Table 1.

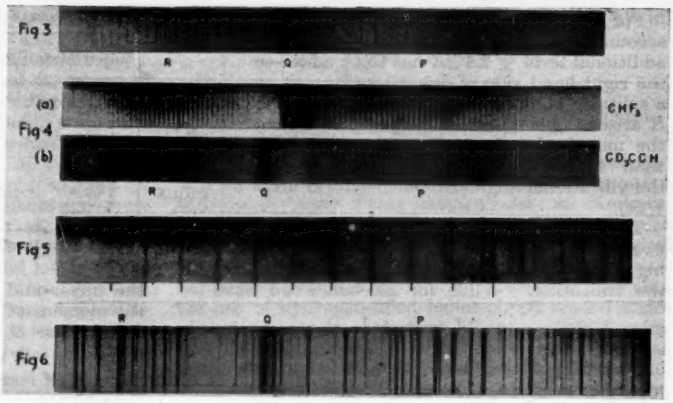


Fig. 3. Π—Σ band of HCN at 10,800 A. (after Douglas and Sharma, ref. 17)
Fig. 4. ∥ bands of CHF_3 at 11,640 A. and CD_3CCH at 10,310 A.
Fig. 5. ⊥ band of CH_3Br at 11,060 A. A second overlapping band is visible at the longwave end
Fig. 6. H_2O band at 8230 A.

For non-linear molecules there are, in general, three non-zero moments of inertia about three mutually perpendicular axes (the principal axes). If two of these are equal, we have a symmetric top. A molecule may be a symmetric top on account of its symmetry (for example, CH_3Cl, CH_3CN, CF_3CH_3) or it may be accidentally a symmetric top. In either case, the rotational energy-levels of a given vibrational level follow the formula (disregarding centrifugal stretching terms)

$$F_v(J,K) = B_vJ(J+1) + (A_v-B_v)K^2, \qquad (3)$$

where A_v and B_v are related to the moments of inertia I_A about the top axis, and I_B about an axis perpendicular to it in the same way as for linear molecules, that is,

$$A_v = A_e - \Sigma\alpha_i^A(v_i+\tfrac{1}{2}) \text{ and } A_e = \frac{h}{8\pi^2cI_A^{(e)}} \qquad (4)$$

$$B_v = B_e - \Sigma\alpha_i^B(v_i+\tfrac{1}{2}) \text{ and } B_e = \frac{h}{8\pi^2cI_B^{(e)}}. \qquad (5)$$

The quantum number J, as before, represents the total angular momentum, while K represents the component of J in the direction of the figure axis (top axis). Consequently, one has

$$K = 0, 1, \ldots, J.$$

Fig. 1*b* shows the rotational levels for the case $A > B$. For each value of K there is now a series of levels like the one for linear molecules (Fig. 1*a*). If the molecule has a three-fold axis of symmetry (for example, CH_3Cl), the levels for which K is a multiple of 3 have eigenfunctions of a different symmetry from those with K not a multiple of 3 (designated A and E in Fig. 1*b*). These levels have different statistical weights similar to the symmetric and anti-symmetric levels of diatomic and linear polyatomic molecules. The statistical weight ratio is 2 : 1 if the three-fold symmetry is due to three atoms of nuclear spin $\frac{1}{2}$.

For degenerate vibrational levels, on account of the effect of the Coriolis force, an additional term $\pm 2A\zeta_i K$ has to be added to the right-hand side of equation (3), that is, a splitting of the degeneracy proportional to K arises. ζ_i is a Coriolis coupling coefficient the magnitude of which is always smaller than 1, and indicates the magnitude of the vibrational angular momentum (in units $h/2\pi$).

The band structure of transitions between two vibrational levels differs, depending on the direction of the dipole moment of the transition. While for all bands we have

$$\Delta J = 0, \pm 1,$$

in the case of $\parallel$ bands (that is, when the dipole moment variation is parallel to the figure axis) the selection rule for K is

$$\Delta K = 0;$$

in the case of $\perp$ bands it is

$$\Delta K = \pm 1.$$

When, as can happen only for accidentally symmetric tops, the change of the dipole moment is at an angle different from 0° or 90° to the figure axis, we have a hybrid band in which both transitions with $\Delta K = 0$ and with $\Delta K = \pm 1$ occur.

In $\parallel$ bands there is one sub-band with P, Q and R branches for each value of K; and if $A - B$ is not very different in the upper and lower state, all sub-bands coincide very closely so that a simple band with P, Q and R branches arises, the spacing of the lines in the P and R branches being approximately $2B$ as for a Π—Σ band of a linear molecule.

For $\perp$ bands there are two sub-bands ($\Delta K = +1$ and -1) for each value of K, and none of the sub-bands coincides. Rather, the Q branches of the sub-bands form a simple series, of spacing $2(A - B)$, with the P and R branches forming a frequently unresolved background. For molecules that are symmetric tops on account of their symmetry ('symmetrical symmetric tops') because of the term $\pm 2A\zeta_i K$ in the energy formula, the spacing is $2[A(1 - \zeta_i) - B]$. In addition, an intensity alternation arises which, for molecules with a three-fold axis, has the form: strong, weak, weak, strong, . . .

Two examples of $\parallel$ bands of symmetric-top molecules in the photographic infra-red are shown in Fig. 4, one of CHF_3 and one of CD_3CCH. The simple P, Q, R structure is clearly visible. One or two weaker Q branches at the longwave side of the principal Q branch are due to 'hot' bands. The parallel bands of CH_3CN, CH_3I and others in the photographic infra-red do not show this simple structure, since the moment of inertia I_A about the symmetry axis is appreciably different in the upper and lower state of the overtone of a symmetrical CH_3 stretching vibration, and in consequence the different sub-bands of these $\parallel$ bands do not even approximately coincide. On the other hand, the $\parallel$ fundamentals do show the simple P, Q, R structure.

As an example of a $\perp$ band, Fig. 5 shows a band of CH_3Br at 1·1 μ. Only the series of Q branches is visible. It shows the expected intensity alternation—strong, weak, weak, strong. . . .

From the $\parallel$ bands one obtains in the same way as for linear molecules the rotational constants B_v in the upper and lower states. B_0 gives immediately the moment of inertia in the lowest vibrational level. In no case as yet are sufficient data available to determine all the α_i^B and thus obtain B_e and the moment of inertia in the equilibrium position.

From the $\perp$ bands of accidentally symmetric tops one obtains $A_v - B_v$, and therefore A_v. However, for symmetrical symmetric tops on account of the Coriolis interaction one obtains $A_v(1 - \zeta_i) - B_v$, and, since ζ_i is in general not known, one does not obtain A_v. It is possible to obtain A_v from Raman rotation-vibration bands, since, for these, O and S branches occur as well as P, R and Q branches, and the dependence on ζ_i is different for the two sets of branches so that both A_v and ζ_i can be determined. While this has not yet been accomplished in a single case, experiments towards this aim are in progress at Ottawa.

Again, from the moments of inertia, the internuclear distances and angles can be determined only if a sufficient number of isotopic molecules have been investigated, or if assumptions are made about certain of the distances and angles. A number of internuclear distances obtained in this way are collected in Table 2, including some of linear molecules and some obtained from microwave spectra. In all cases these are r_0 values obtained from B_0 values. As mentioned in the discussion of linear molecules, the assumption of equal r_0 values in isotopic molecules may lead to slight inaccuracies, but one would not expect any of these to be greater than 0·01 A.

Table 2. Internuclear Distances in Simple Organic Molecules

	r_0(C—H)	r_0(C≡N)	r_0(C≡C)	r_0(C=C)	r_0(C—C)	Reference Nos.
HCN	1·059	1·157				5
C_2H_2	1·058		1·208			9
C_2H_4	1·071			1·353		11
CH_4	1·094					5
C_2H_6	1·102				1·543	10
CH_3C_2H	{1·056*, 1·097*}		1·207*		1·467	3, 12
CH_3CN	1·092*	1·158*			1·460*	13
C_4H_2	(1·058)†		(1·208)†		1·37$_4$	3

* From microwave spectra. † Assumed to be the same as in C_2H_2.

Table 2 shows a significant variation of the C—H distance depending on whether the C—H bond is adjacent to a single, double or triple bond. An even greater change occurs in the C—C single-bond distance in going from C_2H_6 to molecules in which the C—C bond is adjacent to one or two triple bonds (CH_3—C≡CH, CH_3—C≡N, and HC≡C—C≡CH). Another similar case not included in Table 2 is that of CHF_3 (see Fig. 4), for which, with the assumption of tetrahedral angles and a C—H distance as in methane, one obtains r_0(C—F) = 1·329 A., while for CH_3F r_0(C—F) = 1·385 A. is found.

Molecules like CH_4, for which all three principal moments of inertia are equal, are called spherical-top molecules. For them, the rotational energy formula (3) simplifies to

$$F_v(J) = BJ(J + 1),$$

that is, the same as for linear molecules. However, the high degeneracy of the higher rotational levels is removed by Coriolis interaction. In addition, in molecules like methane the triply degenerate vibrational levels are split on account of the same interaction. As a result, most of the rotation-vibration bands have a rather complicated structure, and the

geometrical parameters are better determined from isotopic molecules (for example, CH_3D and CD_3H for CH_4) which are not spherical but symmetric tops.

For asymmetric top molecules, that is, when all three principal moments of inertia are different, much more complicated energy formulæ hold, and, in a strongly asymmetric case, no simple series of energy levels are obvious. All levels with $K \neq 0$ of the symmetric top are split into two levels, so that for each value of J (the total angular momentum) there are $2J + 1$ sub-levels, the positions of which are governed by algebraic equations of order J. In Fig. 1c, as an illustration, the lowest rotational levels in the ground state of H_2O are plotted. The molecules H_2O and H_2S are the only ones of this type that have been analysed in detail. Fig. 6 shows as an example a photographic infra-red band of water vapour.

A number of cases of asymmetric top molecules have been investigated that are nearly symmetric tops. The isosteric molecules HN_3 and HNCO belong to this class[14,15]. Since these molecules are not symmetric tops on account of symmetry, most of the rotation-vibration bands are hybrid bands, that is, have both a $\parallel$ and a $\perp$ component. The sub-bands of the $\perp$ component are very widely spaced, indicating one very small moment of inertia. This very small moment of inertia can only be accounted for if the three heavy atoms, N—N—N and N—C—O respectively, are very nearly on a straight line, while the H atom is off that line. The much smaller spacing of the lines in each sub-band corresponds to the average of the two large moments of inertia. The moments of inertia of HNCO thus obtained have more recently been confirmed by microwave spectra[16,18].

One may confidently expect that further work on rotation-vibration spectra will lead to important results on the geometrical structure of polyatomic molecules. One of the more important needs is for determinations of equilibrium moments of inertia. For this purpose the rotational constants α_i must be determined as well as the B_e values. The study of rotation-vibration spectra is limited to fairly simple molecules containing only relatively few atoms, because only for them are the moments of inertia small enough and therefore the spacings of the lines large enough to be resolved. As the resolving power of infra-red spectrographs and spectrometers is increased, heavier and heavier molecules will be accessible to this method of attack.

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ARTIFICIAL STIMULATION OF RAIN AT KONGWA

By D. A. DAVIES

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IN a previous communication[1], a description was given of experiments on the artificial stimulation of rainfall then being carried out at Kongwa, Tanganyika, by the Overseas Food Corporation in collaboration with the East African Meteorological Department. This communication refefred in particular to a new technique of cloud-seeding involving the use of hydrogen-filled balloons. A second series of experiments is at present being conducted using this new technique both in the original form as already described and also in a modified form.

The experiments using the modified form of balloon technique are based upon the suggestion of Ludlam[2] that hygroscopic particles might be successful in inducing rainfall from well-developed cumulus clouds which have not reached the freezing-level. According to theory, the introduction of such particles will result in the production in the cloud of water-drops of larger size than those otherwise present. These larger drops will have a different rate of fall under gravity than the others and will thus grow by collision. Each such drop will eventually reach a size when it will split into smaller drops, each of which will still be larger than the cloud droplets. A chain-reaction process will thus be established, and rain will be produced.

It is recognized that much of the rain in the tropics falls from clouds which do not reach the freezing-level, and the method described may thus have a much wider field of application in East Africa than the previous methods used at Kongwa, involving the use of silver iodide, which only becomes effective as a seeding-agent at temperatures several degrees below freezing.

The seeding-agent being used is a mixture of 90 per cent sea salt and 10 per cent calcium chloride by weight. The mixture is ground to particle sizes ranging from 5 μ to 100 μ with a peak around 50 μ. Special precautions are taken to keep the powder thoroughly dry before use. The powder is conveyed into the cloud by means of hydrogen-filled balloons, each balloon carrying a small canister containing about 15 gm. of the powder. Dispersal within the cloud is effected by enclosing a small charge of gunpowder (about 1½ gm.) which is exploded by a time fuse. The length of the fuse is adjusted to cause dispersal just above the base of the cloud. The substances involved are easy to obtain and inexpensive. In addition, the method of dispersal is inexpensive, especially when compared with the cost of employing aircraft for the purpose, which is the method used in most experiments of this kind.

It should be noted that, with the technique described above, the explosion is merely to cause dispersal of the seeding-agent, and the method can therefore be used for dispersing any seeding-agent in powdered (or liquid) form. In the silver iodide method, however, the explosion plays an essential part in the actual production of the silver iodide particles.

To facilitate the subsequent statistical analysis of the results of the experiments, a strict three-day cycle is being followed with the silver iodide method on the first day, the hygroscopic method on the second day and no experiments on the third day.

This cycle is being maintained throughout the series of experiments, which will cover a period of about four months. In addition, the point of release of each balloon is adjusted to ensure that the seeding-agent is always released over the same point, this point being in the centre of the Kongwa area of cultivation. As this area is covered with a two-mile grid of rain-gauges, a detailed analysis of rainfall over the area surrounding the point of seeding will be possible.

The aim is thus to carry out a series of experiments which are strictly controlled both in time and space and which are maintained over a fairly long period. It is my belief that positive deductions from any experiments on artificial stimulation of rain are most likely to emerge if the experiments are conducted on such a basis.

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MICHAELSEN INSTITUTE OF THE UNIVERSITY OF COPENHAGEN

A NEW Institute at the University of Copenhagen, to be known as the Michaelsen Institute, has been sponsored jointly by the Michaelsen Foundation, the Carlsberg Foundation, the Rockefeller Foundation and the Danish State, and the building was formally opened on April 16. It houses the Institute of Neurophysiology (director, Prof. Fritz Buchthal) and the Isotope Section of the Zoophysiological Laboratory (director, Prof. H. H. Ussing).

Work in the Institute of Neurophysiology is a continuation of the research carried out since 1933 in the Laboratory for the Theory of Gymnastics, mainly concerned with problems of the physiology of striated muscle and the motor system. In the main, the programme is concerned with the properties of single muscle fibres from various aspects: static and dynamic properties are being investigated in the longitudinal and transverse direction of the muscle fibre, determining longitudinal and torsional elasticity, both at rest and during contraction, the aim being to gain information on the minute structural properties of the fibre and their changes during activity. Attempts are being made to correlate these findings with measurements of birefringence and with direct studies of minute structure as revealed by the electron microscope and X-ray diffraction.

The electrical response of the single fibre, both *in situ* and isolated, is being studied, special stress being put on the influence of the measuring electrode and the surrounding inactive tissue on the parameters of the action potential. After a study of the physical and physiological factors influencing the muscle action potential during voluntary effort, the findings are being applied to action potential analysis in neuro-muscular disorders. A three-channel cathode-ray oscillograph has been developed for the amplification and recording of action potentials, and this permits the use of micro-electrodes with high impedance (input impedance of the amplifiers $> 40 \times 10^6$ ohms at 50 c./s.). A study is in progress dealing with the functional organization of motor unit activity in voluntary contraction.

The mechanical properties of striated muscle are to be correlated with both chemical and electrical reactions. The chemical assay of elements of the nucleotide system is being performed during the development of twitch tension in slowly contracting muscles, which makes it possible to arrest contraction by freezing to $-150°$ C. in the initial phase of a twitch. In connexion with these studies, experiments are being continued on model chemical systems, studying the factors governing the phosphate uptake of myosin threads and solutions when nucleotide is applied to them.

Other problems being pursued relate to neuro-muscular transmission and the influence of different local anæsthetics on propagation velocity in nerve; with the effect of cholinergic substances on cold and pain receptors in the skin; and with the cerebral representation of colour vision.

The activities of the Institute are concerned only with research, and the staff has no teaching obligations. It does, however, act in a consultative capacity, especially to the Neuromedical and Neuro-surgical Divisions of the University Hospital, and the Institute is available for postgraduate training.

The equipment consists of the usual amplifying and recording devices for electrophysiological work, micro-manipulators, and tension and length recorders for work on isolated fibres. This equipment has in part been developed by the physiological and the engineering staff, and has been constructed in the workshop of the Institute.

Work in the Isotope Laboratory is concerned with the study of the active transport of inorganic ions across isolated surviving animal membranes. An experimental device has been developed by which it is possible to determine the part played by any particular active transport process in producing electric currents in a short-circuited living membrane. Thus, it has been demonstrated that the electric current generated by the isolated frog skin—in contact with Ringer solution on both sides—arises solely from active transport inward of sodium ions. It is intended to study the kinetics and dependency upon metabolic poisons of this and other active transport systems. The detailed analysis of the ionic movements is performed by means of isotopes. The Laboratory has available a number of conventional Geiger–Müller counters and also possesses arrangements for the automatic counting of radioactive samples. Moreover, there are facilities for determining heavy water according to the gradient-tube method; at present, this equipment is being used for determining the total water phase in dehydrated infants, but its main use is in connexion with the study of the permeability of living membranes to water. A separate project is concerned with the further development of radioautographic methods. The major aim of this work is to obtain quantitative autography of hard beta-ray emitters. Besides doing research of their own, the members of the staff act as advisers on isotope work to scientific workers from other laboratories.

Three floors of the Michaelsen Institute are occupied by the Institute of Neurophysiology, and one floor by the Isotope Section of the Zoophysiological Laboratory. The former has available eleven laboratories and a library, one small workshop for use of the staff and a machine shop for the construction of equipment, one chemical laboratory, including a cold room, a constant-temperature room, an operating room, a room for post-operative animals, and a dark room on each floor. The Isotope Laboratory has at its disposal seven laboratories and a small workshop.

The rooms are of a standard size, 5·4 m. × 4·4 m. Installations (gas, water, compressed air and a reserve pipe) are led around the room over and under a small shelf (27 cm.) fixed to the wall at table height, and water outlets are built in this shelf. Electrical installations are separate, with a main switch for each room. The wiring consists of lead-shielded cables which are led around the room with multiple outlets at every 1½ m. for 220 V. D.C., 110 and 220 V. A.C., battery voltage and earth. In addition, one of these outlet boxes, with flexible connexions, is placed in the middle of the room. The potential difference between the conducting surfaces in a laboratory (screen of electrical installations, gas and water pipes, etc.) is less than 10 mV. Ice boxes in five of the laboratories are supplied by a central refrigerating unit. They contain a refrigerating mixture which can be piped to any desired location.

The furniture consists of interchangeable units, 1·08 m. × 0·5 m., tables, and drawer and shelf cupboards. By standardizing the room-size, installation and furniture, it has been possible to keep the building expenses to a reasonable figure (£13/cu. m.).

UNITED STATES NATIONAL ACADEMY OF SCIENCES

AT the annual general meeting of the United States National Academy of Sciences, held in Washington, D.C., during April 28–30, the following officers, new members and foreign associates were elected.

Treasurer: W. J. Robbins, director of the New York Botanical Garden, for a further four-year term.

New Members of Council: R. F. Loeb, professor of medicine, College of Physicians and Surgeons, New York; and W. M. Stanley, chairman of the Department of Biochemistry, University of California, Berkeley.

New Members: F. Albright, associate professor of medicine, Harvard Medical School; R. McL. Badger, professor of chemistry, California Institute of Technology; H. R. Byers, chairman of the Department of Meteorology, University of Chicago; C. Chevalley, professor of mathematics, Columbia University; G. M. Clemence, head astronomer, United States Naval Observatory, Washington, D.C.; L. R. Cleveland, professor of zoology, Harvard University; J. S. Fruton, professor of biochemistry, Yale University School of Medicine; C. H. Greenewalt, president of E. I. du Pont de Nemours and Co., Inc., Wilmington, Del.; D. T. Griggs, professor of geophysics, Institute of Geophysics, University of California, Los Angeles; S. B. Hendricks, chief chemist, Bureau of Plant Industry, Soils and Agricultural Engineering, U.S.D.A., Beltsville, Md.; H. H. Hess, head of the Department of Geology, Princeton University; C. L. Hubbs, professor of biology, Scripps Institute of Oceanography, LaJolla, Cal.; W. S. Johnson, professor of organic chemistry, University of Wisconsin; B. P. Kaufmann, Department of Genetics, Carnegie Institution, Cold Spring Harbor, N.Y.; C. K. M. Kluckhohn, professor of anthropology, Harvard University; D. B. Lindsley, professor of psychology, University of California, Los Angeles; P. D. McMaster, member of the Rockefeller Institute for Medical Research, New York; C. G. Niemann, professor of organic chemistry, California Institute of Technology; C. L. Pekeris, member of the Institute for Advanced Study, Princeton; N. F. Ramsey, jun., professor of physics, Harvard University; E. Segre, professor of physics, University of California, Berkeley; R. Serber, professor of physics, Columbia University; F. H. Spedding, head of the Department of Physical Chemistry, Iowa State College; L. Spitzer, jun., director of Princeton University Observatory; G. L. Stebbins, jun., professor of genetics, University of California, Berkeley; E. L. Tatum, professor of biology, Stanford University; V. F. Weisskopf, professor of physics, Massachusetts Institute of Technology; J. A. Wheeler, professor of physics, Princeton University; J. W. Williams, professor of chemistry, University of Wisconsin; and D. W. Woolley, member of the Rockefeller Institute for Medical Research, New York.

Foreign Associates: N. Bjerrum, professor of chemistry, Royal Veterinary and Agricultural College, Copenhagen; T. Reichstein, director of the Organic Laboratories, University of Basle; and H. U. Sverdrup, director of the Norsk Polarinstitutt, Oslo.

The following four gold medals have been awarded by the Academy: *Alexander Agassiz Medal*, to Dr. Harry A. Marmer, United States Coast and Geodetic Survey; *Henry Draper Medal*, to the late Dr. Bernard Lyot, Meudon Observatory, Paris; *Daniel Giraud Elliot Medal*, to Dr. Henry B. Bigelow, Harvard University; and *James Craig Watson Medal*, to Dr. Herbert R. Morgan, Yale University.

The Agassiz Gold Medal, established by Sir John Murray in 1911, is awarded "for original contribution in the science of oceanography to scientific men in any part of the world". Dr. Marmer, in addition to his leadership in the programme of tidal surveys along the coasts of the United States and its dependencies, initiated the co-operative tidal programme on the west coast of South America in 1941, and the tidal survey of the western Pacific Islands in 1947. These projects have made available to oceanographers accurate, long-period records for large areas where previously very few observational data were available. He has introduced methods, analyses and criteria which permit the separation of the effects of local crustal deformation from those of eustatic changes in sea-level.

The Draper Medal, which the Academy bestows from time to time in recognition of outstanding contributions in the field of astrophysics, has been awarded to Dr. Lyot for his work in solar physics and in particular for his development of the coronograph, whereby the inner corona of the sun may be observed continuously; previously it had only been possible to observe the solar corona at times of a total solar eclipse. Dr. Lyot, who died recently in Cairo while directing the French solar eclipse expedition at Khartoum, was elected a foreign associate of the Academy in 1949.

Dr. Bigelow is the senior author of "Fishes of the Western North Atlantic", Part 1, published in 1948 as Memoir No. 1 of the Sears Foundation for Marine Research, and it is for this that he receives the Elliot Medal, which is for the year 1948, an award which is made annually to the author of the work in zoology or palæontology considered by the Academy to be the most meritorious of the year. The volume covers in three separate parts the lancelets, the cyclostomes and the sharks, with Dr. Bigelow as senior author for each part and associated in each with another author. Dr. Bigelow has been a moving spirit in work on the fish fauna of the

western Atlantic Ocean during the past two decades, and his book is another of his contributions on the elasmobranchs and related fishes, to which may be added his important published researches in such invertebrate groups as the Medusæ, Siphonophores and Cœlenterates.

The Watson Medal, established in 1874, is awarded "from time to time to the person in any country who shall make any astronomical discovery or produce any astronomical work worthy of special regard as contributing to our science", and Dr. Morgan's outstanding contribution to astronomy is his interpretation of his transit-circle observations. Since 1947, after his official retirement as principal astronomer of the United States Naval Observatory, he has taken part in the construction of an improved catalogue of the best-determined stars, a work which is under the joint auspices of the Naval Observatory, the Watson Scientific Computing Laboratory and the Yale University Observatory. Dr. Morgan's discussion of his own observations, as well as of other series, has contributed materially to present knowledge of the fundamental constants of astronomy.

CARNEGIE INSTITUTION OF WASHINGTON

ANNUAL REPORT FOR 1950–51

YEAR Book No. 50 of the Carnegie Institution of Washington covers the period July 1, 1950–June 30, 1951*, and consists mainly of the usual competent administrative reports of the several departments, together with auditors' report and a bibliography of publications during the year. Once again, what lends distinction to the whole is the annual report of the president, Dr. Vannevar Bush, in which Dr. Bush once again ranges over science in the United States and selects for comment some features which are of interest to the world of science as a whole. Looking, for example, once more at the function of the voluntary institution in the context of the new situation in which, in the United States, the National Science Foundation is one factor, and commenting on the need to preserve freedom of action and initiative, Dr. Bush remarks on the danger that, in the effort, by State intervention, to protect the unfortunate or underprivileged, may be quenched the spark which has so far given the United States a higher standard of living than any other part of the world enjoys.

That danger exists in Great Britain also, and Dr. Bush's further warning to his countrymen that a State devoted to protecting all its citizens from all the normal hazards of life may become merely a battleground for highly organized special interests should be heeded equally in Britain. The consequences of a growing dependence of universities on government funds and the trend towards a control of research which could become bureaucratic are recognized by Dr. Bush, but with no more dismay than that with which he witnesses the dwindling resources of the Carnegie Institution itself in comparison with those which the Federal Government devotes to research. Such government intervention he accepts as inevitable, and respects it as he does the quality of much of the industrial research to which he pays tribute. Unperturbed, he insists that the voluntary or independent institution has a contribution to make out of all proportion to its quantitative magnitude by reason of its quality and orientation.

The essential function of such an institution is, in Dr. Bush's opinion, to seize the opportunities within its range which appear to be neglected but are of large potential for enhancing the basic understanding of Nature and of man. Particularly is this true of the unconventional. The independent institution can afford to take risks, even of complete failure, which no government institution could without fear of repercussions. It can examine a theory which has yet to gain acceptance in powerful scientific circles, and can search for any new knowledge which it regards as basic to man's understanding of himself or his environment, or as likely to broaden his conception of his place in the universe.

From the research activities of the year, reviewed more fully in the departmental reports, Dr. Bush selects for mention first the observations now beginning to come from the 200-in. Hale telescope at the Mount Wilson and Palomar Observatories. Observations made by Humason with the prime-focus spectrograph of the Hale telescope have included three nebulæ with velocities up to 61,000 km./sec., or more than 20 per cent of the velocity of light. When combined with the results of the more precise methods of measurement of nebular distance now being developed, these new velocities should lead to a much more accurate formulation of the distance–velocity law. Continued studies by H. W. Babcock of the general magnetic field of stars has led to the discovery of the largest field so far observed—9,000 gauss in *HD* 133029. This star has a field fluctuating down to 5,000 gauss, and it appears that stars with variable spectra are members of a much larger group of magnetically variable stars. Variability of spectrum is only observed in stars of which the magnetic oscillations are of large amplitude with a regular period of only a few days, and the magnetic polarity of which reverses with each period.

New experimental methods developed at the Geophysical Laboratory of the Institution have accelerated progress in the investigation of hydrous silicate systems. The nature and mechanism of processes in the formation of serpentine, granites and pegmatites have been demonstrated and unforeseen complexities revealed in the composition and forms of the feldspars. Advances in the techniques for quantitative studies of silicates at high pressures and temperatures are giving a clearer picture of geological processes within the earth and leading to new methods for the study of metamorphic rocks and their rock-forming minerals, as well as providing a clue for unravelling some mysteries of magma formation and for understanding the strong forces of movement and deformation that occur in the crust of the earth.

In the Department of Terrestrial Magnetism the development of a means of approximate estimation of the total ionization of the upper region from the ionospheric record, replacing the older values of ion density, has removed much of the uncertainty as to the mechanisms producing the principal ionization in the high atmosphere. Simultaneous observations using three different sets of ionosphere equipment spaced at different distances in triangular or linear formation were used for studies of winds and turbulence in the very high atmosphere, and large

* Carnegie Institution of Washington. Year Book No. 50, July 1, 1950–June 30, 1951, with Administrative Reports through December 14, 1951. Pp. xxxv+260. (Washington, D.C.: Carnegie Institution, 1951.) 1 dollar.

differences in the ionosphere overhead were unexpectedly found for stations only thirty miles apart. The biophysics group has studied the pathways and intermediate products in the synthesis of nucleic acid and protein constituents by supplying the nutrient medium with certain tracer-labelled compounds, selected as being specific compounds that may be formed in intermediate stages of the synthesis. The new procedures have been throwing light on the physical and chemical mechanisms by which the components of a protein are reproduced and on the degree of variability in precise constitution which is normal, for example, in the successive reproduction of a given protein. In particular, the method has been used for the study of the utilization of sulphate ions by *Escherichia coli* and the role of carbon dioxide in protein synthesis.

Further experimental work has been undertaken in the Department of Plant Biology to determine the conditions favouring the higher rates of growth of *Chlorella* with the view of the possible utilization of algæ for food and industrial raw materials. Arrangements have been made for A. D. Little, Inc., to set up and operate a *Chlorella* pilot plant, while further work in the Department has shown that the collection of *Chlorella* by continuous settling and re-use of the same growth medium for repeated batches of culture is practicable. Measurements of the fluorescence spectra of a red alga have provided evidence of the transfer of light energy absorbed by the accessory pigment phycoerythrin to chlorophyll and also to phycocyanin in the living alga. The time course of the development of the precursor of chlorophyll, protochlorophyll, has been followed in barley seedlings grown in the dark, and oxygen is not evolved in the photochemical transformation of protochlorophyll to chlorophyll. Extensive field investigations of the growth of grass hybrids have continued, including growth studies of *Poa* hybrids and species under controlled conditions, their climatic tolerances and the genetics and evolution of *Poa*. The possibilities of using the results of experiments in controlled greenhouses to evaluate the productivity of specific grass strains in different natural climates has been further investigated. A preliminary study of the tertiary floras of Japan from Hokkaido to southern Honshu, with special reference to the distribution of *Metasequoia* and other members of the Arcto-Tertiary flora, has confirmed the hypothesis that changes in forest distribution during the past seventy million years have been of the same order and in the same direction in both Asia and North America.

The work of the Department of Embryology was interrupted by important changes of staff during the year; but although the output of published work was lower, progress was made in the investigations on the biochemistry and physiology of uterine muscle, on the transference of phosphorus across the placenta and in renal physiology. The rate of loss of the blood substitutes, dextran and polyvinylpyrrolidone, from the blood capillaries of organs of the dog was being investigated, and also the secretory activity of the ciliary body of the eye.

The Department of Genetics has been actively engaged in research pertaining to genes and the mechanical basis of heredity, and the report includes a full account of Dr. B. McClintock's work on mutable loci in maize, which has shown that at any one genelocus different alterations can occur, each initiating a particular kind of phenotypic expression of the initial instability. The methods developed in these studies will permit study of the mutation process by concentrating on the nuclear mechanisms that control when, where and how particular factors or genic components will be reactive in different cells and tissues of an organ. Continued studies of the mutagenic action of manganous chloride on *Escherichia coli* indicate that the action depends on the physiological state of the bacteria, which can be readily changed by varying the environmental conditions of treatment. In studies of the course of digestion of plant and animal cells, it has been demonstrated conclusively that trypsin in aqueous solution can degrade substrate materials of fixed cells. As the enzyme attacks specific linkages in the protein molecules, nucleic acids are released from their state of combination, and the cellular materials become capable of swelling like gels when treated with inorganic salts and then water. This swelling in an intact cell rather than the dissociation of the protein molecules accounts for the disintegration. Methods developed in these studies have also shown that X-ray treatment of living larvæ of *Drosophila* alters the pattern of combination of nucleic acids and proteins in their salivary gland cells so that they swell less on treatment with trypsin, salts and water. Other X-ray studies have shown that the amount of crystalline trypsin inactivated varies with the solvent, the concentration of the enzyme and the *p*H of the solution, whereas with *Escherichia coli* the first direct genetic evidence has been obtained that the nucleus of the bacterial cell is actually a carrier of hereditary material. Observations on the production of heterozygous phage particles in crosses between mutants of the bacteriophage T_2 have indicated that genetic doubling is probably a constant feature of bacteriophage multiplication.

FOREST POLICY IN UGANDA PROTECTORATE

IN the 1949 forestry report for Uganda Protectorate (see *Nature*, **168**, 507; 1951) it was stated that local governments were being encouraged to take over forestry work in areas where there were sufficient forests and that the district forest officer would act less and less in his official and trained capacity in these forests. It was pointed out that a similar action has been taken in other parts of the British Commonwealth—for example, in the Madras Presidency during the present century, when forests of the type in question were handed over to the care and management of the village Panchayats (communities). The result has been that a very large area of these forests has been destroyed by over, and wasteful, utilization; erosion has set in, with a reduction in water supplies; and the Forest Department has now been called in and has a difficult and uphill job in some areas. Yet thirty years ago these forests were under the efficient management of the Department.

In the forestry report for Uganda, covering the year ended December 1950*, the proposed devolution of the management of local forest areas is further developed. "This policy," says the report, "is resulting in the devolution of 'minor forestry' from the Protectorate Government. 'Minor forestry' may be defined as the management of the smaller reserves

* Uganda Protectorate. Annual Report of the Forest Department for the Year ended 31st December, 1950. Pp. iv+51. (Entebbe: Government Printer, 1951.) 3*s*.

of purely local significance; the supervision of village forests; the creation of plantations of fast-growing trees for supplies of building poles and firewood necessary for the economy of rural areas and minor townships . . . etc." Also, the local government should take over the management of all natural tree growth on Crown lands. The report continues: "Although it is a prior condition that the local government shall have the will and competency to undertake the additional duties attendant on devolution, it is a disagreeable fact that no local government has as yet the competency. The management of local forestry is still very largely the concern of the District Forest Officers, and local staffs are for the most part painfully inadequate. Few local governments are able to pay wages comparable with those given by the Protectorate; and even if suitable men are produced for training, they are young men who lack experience and consequently lack authority with chiefs and the people. In many districts the only alternative appears to be to second Protectorate Rangers". The management of the classes of forest herein contemplated, which are of primary importance to the local communities, is very far from being the easy or simple job which the Civil departments of the British Administration have so often regarded it in the past. The trained forest officer's job was, and is, considered to be in the big forests from which timber and revenue come—otherwise the Department is not paying its way.

In some parts of the world, by no means confined to the British Commonwealth, there are large populations living in hot countries where over great tracts of land the forest is represented by a scrub of varying height, growth, consistency and species, with grass for grazing, and so forth, the maintenance of which is essential to the well-being of the local populations and to their agricultural occupations. The continuance and, if possible, improvement of this type of forest, for forest it is, are as vital in the administration of the country as are the big timber forests, and demand often the highest skill of the trained and experienced forest officer—the district forest officer alluded to in the Uganda report. Such knowledge is not possessed by the Civil authority, nor by village communities, and to apply it requires a greater authority than that of a Protectorate ranger.

E. P. Stebbing

THE OPENING OF MILK BOTTLES BY BIRDS

THE opening of milk bottles by birds is now a well-known habit throughout most of the British Isles and has previously been described in *Nature* (**165**, 435; 1950). Further information has now been collected by R. A. Hinde and James Fisher, and includes records from the British Isles and other countries (*British Birds*, **44**, No. 12; 1952).

In Sweden, as in Britain, observations have been made of the opening of milk bottles by blue tits and great tits. The habit is said to be widespread and that "magpies and blackbirds" also raided the bottles. In Vendolso tits have been observed opening coffee cream bottles. In Denmark the habit is also well known, and, in suburban districts, is said to be almost a nuisance; the main birds are the great tit and the great spotted woodpecker (*Dendrocopus major*). In Copenhagen the opening of bottles by great spotted woodpeckers is reported to be a general practice. Along the south border of the Geel forest jackdaws have been seen opening bottles.

Inquiries made by Dr. L. Tinbergen in Holland indicate that bottle opening occurs in at least twenty-one localities south of the Zuider Zee; in all cases where the bird was certainly identified it was a great tit. Milk bottles practically disappeared from Holland during the War and only became reasonably common again in 1947–48. It is unlikely that many tits which had learnt the habit in pre-war years still survived at this date, so the habit must have originated in all the recorded localities since 1948. Since great tits are relatively sedentary birds, it seems certain that the habit was started in many different places and by many individuals.

In the United States a photograph of a Steller's jay (*Cyanocitta stelleri*) opening a milk bottle has appeared in a Seattle newspaper.

Although no experimental analysis of the behaviour involved in the opening of milk bottles has yet been made, further observations in the field enable the discussion to be carried further. Previously the processes were considered in two parts—the 'recognition' of the milk bottle as a potential supply of food and the technique of opening the bottle. The actual opening of the bottle probably depends on innate motor patterns, and the study of tits in the field has confirmed this view. The movements used are the same as those used when feeding on natural foods. For example, the hammering action with which foil caps are punctured is very similar to a motor pattern used in opening nuts, and the tearing action often used on cardboard tops is similar to a movement used in tearing bark from a twig.

It has been suggested that the initial 'discovery' of the bottle as a source of food may be a logical consequence of the feeding habits of tits. They appear to have an inborn tendency to inspect a great variety of conspicuous objects which contrast with their surroundings, and to test their palatability. If the outside of the object is unpalatable, they may attempt to open it by hammering—hammering seems to be evoked by the sound of a hollow object. In fact, it seems that, when tits are looking for food, objects with certain very general characteristics may be sufficient to release a more limited type of searching behaviour (such as flying to the food). By a succession of similar steps (hammering, etc.), evoked by successively more specific stimuli, a reward may eventually be obtained. It so happens that milk bottles have sufficient characteristics in common with the natural foods for tits occasionally to 'discover' them in the course of their normal searching.

When a bird has fed once or a few times at milk bottles, it will learn to return to them on later occasions, presumably by a form of trial-and-error learning. On these subsequent occasions the bird may come to respond to quite different stimuli from those which controlled its behaviour the first time. For example, if milk bottles with differently coloured stoppers are available, the tits will often concentrate their attacks on those having stoppers of one particular colour—presumably because the colour of the top was one of the characters which the bird learnt on the first visits.

Hinde and Fisher also suggest that the apparent copying of the behaviour by other individuals is probably due to another process—local enhancement—which modifies the appetitive behaviour of feeding and is initially independent of reward.

LETTERS TO THE EDITORS

The Editors do not hold themselves responsible for opinions expressed by their correspondents. No notice is taken of anonymous communications

Phase Determination in the X-Ray Diffraction Patterns of Complex Crystals and its Application to Protein Structure

THE phases, or signs in cases of central symmetry, of X-ray reflexions from organic crystals can only be determined unambiguously and without prior assumptions by the use of methods employing heavy atoms or isomorphous replacements. In cases where these methods cannot be used, they have been determined hitherto largely either by means of conjectural molecular models with subsequent refinement, or by the use of various inequalities such as those of Harker and Kasper[1] and later elaborations, all of which depend on the existence of discrete scattering maxima corresponding to a finite number of atoms. In very complex crystals such as proteins these methods are inapplicable or of very doubtful validity, as the individual atoms are very numerous—usually more than a thousand—and not easily resolved. Harker has attempted to overcome this difficulty by the use of hypothetical, large, spherical groups or 'globs', but these are difficult to justify on physical and chemical grounds.

It has occurred to me that, in just such complex crystals, use can be made of the physico-chemically reasonable assumption that the molecule occupies a large portion of the cell—up to two-thirds—in proteins, the rest being water. Very high or low concentrations of scattering material are unlikely for, if they occurred, they would reveal their presence by low-order reflexions of a strength that is not observed. The condition that the variation from the mean density must be approximately uniform imposes further conditions on diffraction phase relations. That the variation from the mean density is, however, far from statistical is shown by the occurrence of close groups of relatively strong planes of four or more times the average intensity, nearly contiguous in reciprocal space, which I have called 'constellations'. These are separated by regions of small or absent reflexions.

It can be shown that the main features of the structure must be determined by the contribution of these strong or *significant* reflexions, the much larger number of weaker reflexions acting only as modifiers. Each of these constellations in reciprocal space must correspond to a wave packet in real space the frequencies and orientations of which are determined by the orders of the planes. The position of the most important maxima in the cell depends, however, only on the phase relationship within the constellation. Certain arrangements can be excluded from the start. Dealing, for simplicity, with the case of a projection with central symmetry, as in a monoclinic *b*-axis projection, it can be shown at once that not only

$$\Sigma F_{hol} \approx 0,$$

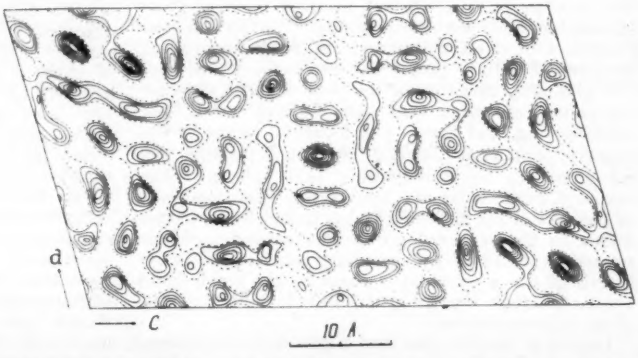
for otherwise there would be an accumulation of density near the origin, but also that

$$\Sigma F_{2h,0,2l} \approx \Sigma F_{2h+1,0,2l} \approx \Sigma F_{2h,0,2l+1} \approx \Sigma F_{2h+1,0,2l+1} = 0.$$

These conditions, though necessary, are not sufficient. It can be further shown that in any constellation the strong reflexions not only cannot be of the same sign, but also cannot have any regular alternation of sign. For example, in an array of seven, not only is $+++++++$ and the virtually identical $+-+-+-+$ inadmissible, but also $-++-++-$ and $++-++-+$, as such arrangements correspond to alignments of strong peaks in one or two parts of the cell only. Only highly irregular arrangements such as $+++--+-$ or $--+++--$ give an approximately even distribution throughout the cell.

This condition makes it possible to approach the problem of sign determination by the method of exhaustion without facing an impossibly formidable task—there are 2^{800} possible sign permutations in the (*h0l*) projections of ribonuclease, or 2^{105} for significant planes alone. The method proposed is the following. First, suitable constellations are selected with three to ten significant reflexions in each; there are some twenty such in the ribonuclease (*h0l*) projection. Next, a limited number of geometrically distinct sign assignments, excluding those certain to give impossible distributions, are made inside each constellation and the corresponding Fourier projections calculated. Some of these will violate the conditions of uniformity at this stage and can be rejected. The subsequent stages consist of the combination by stages of the contributions of the different constellations; each pair can be combined in four distinct ways on account of symmetry conditions. The combined projections can now be tested for their contributions to the areas where planes are observed to be weak and those that give strong contributions there rejected. The remaining Fourier projections, of which there will be a fairly large but not unmanageable number, can now be examined with regard to their physico-chemical plausibility, no assumptions about which, other than quasi-uniformity, have hitherto been made.

It is too early yet to know whether such a method is practicable even with the use of machines and whether it can give a complete and unambiguous answer; but even if it fails to do so, it can give very useful indications. A first effort, making use of



Ribonuclease (*h0l*) Fourier projection (arbitrary densities, only positive contoured)

fifty-two reflexions, among the 890 observed by Carlisle, Scouloudi and Spier (private communication) for ribonuclease ($h0l$), in four constellations, was carried out, using Beevers–Lipson strips without any calculating machines, in five days. The result is shown in the accompanying diagram. It shows a number of peaks of varying height which seem to be at intervals averaging 5 A. in somewhat wavy alignments also 5 A. apart in the direction of the c-axis, which may correspond to the direction of protein chains. While not claiming that this presents a true picture of the protein molecule, it can be claimed that it brings out some of its invariant character, namely, the part dependent only on the intensities and not the phases of the X-ray diffraction pattern. Fuller results, including a general theory of phase determination, will be published elsewhere.

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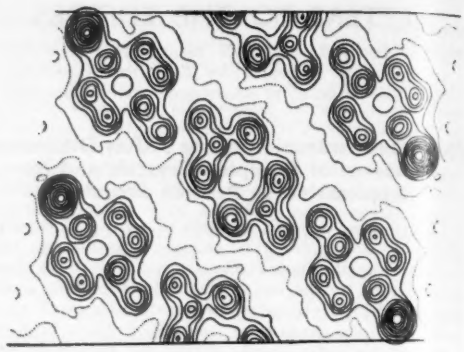
April 29.

[1] Harker, D., and Kasper, J. S., *Acta Cryst.*, **1**, 70 (1948



Plot of the [010] projection of the electron density of β-(*p*-chlorphenyl)-propionic acid. The contour interval is 1 e/A.^{2} except within the chlorine atom above 4 e/A.^{2}, where the interval is 2 e/A.^{2}. The 1 e/A.^{2} contour is dotted. The portion plotted has a horizontal edge $a/2$ and an oblique edge $2c$. The origin is in a centre of symmetry projected at the centre of the plot

Crystal Structures of Two Para-substituted Phenylpropionic Acids

β-Phenylpropionic acid is of particular interest as an inhibitor in the carboxypeptidase system[1], in addition to its general interest in biology. One of us[2] has shown that the unsubstituted acid is not amenable to X-ray analysis, having eight molecules in a monoclinic primitive cell. We have therefore studied the para-substituted chlorine and bromine compounds. They are isomorphous, with cell data as follows:

β-(*p*-chlorphenyl)-propionic acid:
$a = 30{\cdot}01$ A., $b = 5{\cdot}078$ A., $c = 5{\cdot}744$ A., $\beta = 98° 30'$, $P2_1/a$;

β-(*p*-bromphenyl)-propionic acid:
$a = 30{\cdot}15$ A., $b = 5{\cdot}143$ A., $c = 5{\cdot}827$ A., $\beta = 98° 40'$, $P2_1/a$,

in each case with four molecules per unit cell. Weissenberg multiple-film techniques were used in visual evaluation of the reflexion intensities, and the precession camera was used in determining the cell dimensions and in checking the orientation adopted. The [010] projections are well resolved for both these substances and are quite similar. That for the chlorine compound is illustrated in the accompanying diagram. The [001] projections are less well resolved.

Preliminary analysis of the data for the chlorine compound indicates that the chlorine atom, the benzene ring, and the α- and β-carbon atoms of the aliphatic acid chain lie very close to one plane, not far from the crystallographic $(4\bar{1}1)$ plane. The carboxyl group is tilted a few degrees from the plane of the rest of the molecule and is linked by hydrogen bonds to the carboxyl group of a second molecule related to the first by a symmetry centre. The bond-length of the α—β bond is close to the single-bond value, whereas the other two C—C bonds in the chain appear shortened.

Details of bond-lengths and angles will be discussed elsewhere after further refinement has been carried out. Studies are also in progress on the related trans-β-phenylacrylic acids, and on the *ortho*-substituted phenylpropionic acids, which are of interest in enzyme studies.

We are indebted to the National Cancer Institute of the National Institutes of Health, U.S. Public Health Service, for grants in support of this research, to Prof. Ernst Berliner, of Bryn Mawr College, who supplied the two compounds investigated, and to Mrs. Alice Sword Weldon for assistance with computations.

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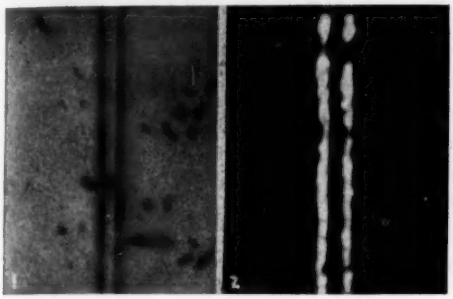
[1] For example, see Smith, Emil L., and Lumry, R., Cold Spring Harbor Symp. Quant. Biol., **14**, 168 (1950).
[2] Patterson, A. L., *Phil. Mag.*, **3**, 1252 (1927).

Measurement of the Thickness of Transparent Films with the Light-Profile Microscope

The light-profile microscope technique, described by Tolansky[1], has been adapted by us for the determination of the optical thickness of relatively thick transparent films. A transparent film, bounded by media with refractive indices differing from that of the film, has two reflecting surfaces; when observed with a light-profile microscope these two surfaces produce a double image, from the separation of which it is relatively easy to derive the ratio t/μ, in which t is the thickness and μ the refractive index. This is of much value in so far as direct interferometry, using, for example, fringes of equal chromatic order, gives the value μt. The combined methods thus give both μ and t.

For films exceeding a few microns in thickness, difficulties due to depth of focus prevent precise focus simultaneously on both images. We have found it satisfactory to set at an intermediate focal plane, such that both images are defocused by about the same amount. That the compromise is satisfactory is shown by a thickness evaluation of 23 microns with an 8-mm. objective (depth of focus 2 microns) for a sheet of mica of thickness known to be 22½ microns.



× 350 × 300

As an example of the technique, Fig. 1 shows the double image given by a sheet of mica. On making corrections for the known angle of incidence, previously determined when using the light-profile, and by combining with interference fringes, the values found were $\mu = 1{\cdot}55 \pm 0{\cdot}03$ and $t = 10{\cdot}3 \pm 0{\cdot}2$ microns. Fig. 2 shows the slit light-cut given by a thin piece of 'Cellophane', giving $\mu = 1{\cdot}56 \pm 0{\cdot}04$ and $t = 22{\cdot}5 \pm 0{\cdot}5$ microns. It is apparent that in both cases a 2 per cent accuracy is attainable.

The method has been successfully applied to the determination of the local variation in thickness of thin collodion, Canada balsam, and liquid films on crystal surfaces, and it is clear that the method offers a useful new procedure for film thicknesses exceeding 1 micron in thickness.

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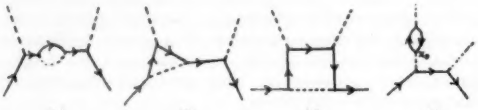
[1] Tolansky, S., *Nature* [169, 455 (1952)].

Radiative Corrections to Compton Scattering and *Bremsstrahlung*

The infra-red catastrophe in the higher-order radiative corrections to electron scattering has been well known and shown to disappear when the virtual processes are considered along with the real processes of the same order. It will be, perhaps, worth investigating the problem of infra-red catastrophe in the case of higher-order radiative corrections to the Compton effect and *Bremsstrahlung* for an electron. In the present communication the results of the calculations for the second-order corrections to the Compton effect and *Bremsstrahlung* by the covariant formalism of Feynman–Dyson are given. The graphs of the two processes are similar and given below:



(1) (2) (3) (4)

In the case of Compton effect, the external dotted lines correspond to one photon absorbed and one emitted. In the case of *Bremsstrahlung*, one of the dotted lines corresponds to the external potential. Diagram 4, corresponding to external vacuum polarization, refers only to *Bremsstrahlung*, while the first three relate to both the phenomena.

The matrix elements have been calculated by Dyson's method, and the ultra-violet divergences have been separated and removed by mass and charge renormalizations. The cross-sections are then evaluated by Møller's invariant formula with slight modifications in the case of *Bremsstrahlung* when the momentum is not conserved. As we are interested in the problem of the infra-red catastrophe, we shall in the following give the cross-sections involving the low-energy quanta only. Thus we have the following results for the cross-sections in natural units ($\hbar = c = 1$):

(1) *Compton effect.*

$$d^{(2)}\Phi'_{\text{Compton}} = \frac{\mathbf{K}^2\alpha^2 d\Omega_{K'}}{2\pi K_0^4}\Big[-\frac{2}{3}(1-\cos\theta)(1+\cos^2\theta)\times \log\frac{K_0^2}{\lambda^2} + 4y\left\{1+\cos\theta-\frac{1}{3}\cos^3\theta+\cos^2\theta\right\}+ \frac{16}{9}-\frac{13\cos\theta}{3}+\frac{16\cos^2\theta}{9}+\frac{5\cos^3\theta}{9}\Big] \quad (1)$$

where $\mathbf{K}$ and $\mathbf{K}'$ are the momenta of the initial and final quanta, θ the angle of scattering, K_0 is the rest mass of the electron, $\alpha = e^2/4\pi$, and $y = \log\dfrac{K_0}{2|\mathbf{K}|}$; λ is the vanishing rest mass of the photon, which is related to the invariant minimum light quantum number K_m by:

$$\lambda\varepsilon = 2K_m. \quad (2)$$

(2) *Bremsstrahlung.* The cross-section integrated over the angular distribution (not the magnitude) of the emitted quantum is:

$$d^{(2)}\Phi'_{\text{Bremss.}} = \frac{-4dK d\Omega_q \alpha^4 Z^2}{3\pi^2|\mathbf{K}|K_0^2}\times\left|\frac{\mathbf{q}}{\mathbf{p}}\right|\times \left(\frac{2}{3}\log\frac{K_0^2}{\lambda^2}-\frac{19}{15}\right), \quad (3)$$

where $\mathbf{q}^2 = \mathbf{p}^2 - 2\,\mathbf{K}\,K_0$.

$\mathbf{p}$ and $\mathbf{q}$ are the momenta of the incident and scattered electrons respectively, and $\mathbf{K}$ the momentum of the emitted quantum.

It is to be noted that the cross-sections (1) and (3) tend to infinity for $\lambda \to 0$, giving rise to an infra-red catastrophe. We must now consider the cross-sections due to (*a*) double Compton effect, involving the scattering of a photon by an electron with the additional emission of a soft photon, and (*b*) double *Bremsstrahlung*, giving the emission of two quanta by the electron. It is obvious that the cross-sections for these processes are of the same order of magnitude as the processes described in diagrams 1 to 4 and given by:

$$d^{(2)}\Phi''_{\text{Compton}} = \frac{2\mathbf{K}^2\alpha^2 d\Omega_{K'}}{3\pi K_0^4}\Big[(1+\cos^2\theta)(1-\cos\theta)\log\frac{\mathbf{K}^2(1-\cos\theta)}{K_0 K_m}\Big] \quad (4)$$

and

$$d^{(3)}\Phi''_{\text{Bremss.}} = \frac{16\alpha^4 Z^2 d\Omega_q dK}{9\pi^2|\mathbf{K}|K_0^2}\times\left|\frac{\mathbf{q}}{\mathbf{p}}\right|\times \left\{\log\frac{4\mathbf{q}^2}{2K_0K_m}-2\right\}. \quad (5)$$

Adding, therefore, the cross-sections (1) and (4), and also (3) and (5), we obtain finally:

$$d^{(2)}\mathfrak{p}_{\text{Compton}} = \frac{\alpha^3\mathbf{K}^2 d\Omega_K'}{3\pi K_0^4}\left[2(1-\cos\theta)(1+\cos^2\theta)\times\right.$$

$$\log\frac{2\mathbf{K}^2(1-\cos\theta)}{eK_0^2} + 6y\,(1+\cos\theta-\frac{1}{3}\cos^3\theta+$$

$$\left.\cos^2\theta) + \frac{8}{3} - \frac{13\cos\theta}{2} + \frac{8\cos^2\theta}{3} + \frac{5\cos^3\theta}{6}\right] \quad (A)$$

$$d^{(3)}\Phi_{\text{Bremss.}} = \frac{4\alpha^4 Z^2 d\Omega_q dK}{9\pi^2|\mathbf{K}|K_0^2}\times\left|\frac{\mathbf{q}}{\mathbf{p}}\right|\times$$

$$\left(4\log\frac{4\mathbf{q}^2}{k_0^2} - \frac{41}{5}\right). \quad (B)$$

These expressions are completely free from the infra-red divergences. The ultra-violet divergences have been already removed by re-normalization methods. Details of this work will be published shortly.

I am indebted to Prof. R. C. Majumdar for suggesting this problem and giving me guidance and encouragement throughout the work.

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Surface Tension and Melting Point

Weale[1] has directed attention to an earlier formula, due to Schytil, according to which the surface tension of a liquid is proportional to $T_m V^{-2/3}$, T_m being the melting point and V the molar volume. Since the number of molecules in a unit area of the surface is $(V/N)^{-2/3}$, the above relation can be interpreted to mean that the surface energy per unit area, and the thermal energy of the molecules in that area, are proportional to each other at the melting point. Numerical calculations show that for most liquids the two are almost equal, if we consider the translational part of the thermal energy only. Thus σ_m, the surface tension at the melting point, is given by:

$$\sigma_m = 3(N/V)^{2/3}kT_m, \quad (1)$$

k being the Boltzmann constant.

A number of unassociated organic liquids obey the above relation. Small discrepancies can often be explained by the fact that the distance, d, between the two adjacent surface layers is not given exactly by $(V/N)^{1/3}$, so that the number of molecules per unit surface is slightly different from that assumed above. The accurate expression for σ_m is then:

$$\sigma_m = 3(N/V)dkT_m. \quad (2)$$

Equation (2) gives an accurate value of σ_m in the case of benzene, where d is known from X-ray diffraction studies[2] to be 3·7 A. If there is any association of the molecules, there is a decrease in their number in the surface layer, and the right-hand side of equations (1) and (2) must be multiplied by an association factor. As an example, the association factor to be used in equation (1) for explaining the observed surface tension of acetic acid is $\frac{1}{2}$, thus showing, in agreement with the general view, that two molecules have become associated to form a single unit.

The ratio $3kT_m/\sigma_m$ gives the area of the surface covered by a single molecule. In the case of those organic compounds in which the hydrocarbon chain is perpendicular to the surface, the cross-section of a single chain can be obtained on multiplying this area by the appropriate association factor. This has been calculated for a few esters and acids (see table), the experimental results for σ_m having been extrapolated roughly from the values given in the "International Critical Tables". The association factor has been taken to be 1 in the case of esters and $\frac{1}{2}$ for the acids, as is generally accepted. The calculated cross-section is in fair agreement with that obtained from X-ray diffraction and from monomolecular layers.

Cross-section of a Hydrocarbon Chain

Substance	σ_m (dynes/cm.)	T_m (° K.)	Cross-section of hydrocarbon chain (sq. A.)
Ethyl formate	36·6	193	21·8
Ethyl acetate	37·7	189	20·5
Methyl propionate	36·7	186	20·7
Ethyl propionate	35	200	23·5
*Iso*butyl acetate	34	173	21
Ethyl *iso*valerate	34	174	21
Acetic acid	28·2	290	21·1
n-Butyric acid	29·6	265	18·5
Undecylenic acid	30·6	298	20
Oleic acid	32·5	287	18·2

Equation (1) gives too high a value of σ_m for the alkali halides, so that we have to assume some degree of association, a conclusion also necessitated by the abnormal values of their Eötvös constants. We may, however, avoid this assumption and obtain the experimental value of σ_m by using equation (2), with the values of d obtained from the spacings of the (111) and (110) planes for the sodium chloride and the cæsium chloride types of lattices respectively, and after making allowance for the thermal expansion from room temperature to the melting point. In the sodium chloride lattice, the (111) planes contain all the atoms of one kind only, so that in order to keep complete molecules in the surface layer we may have to make an additional postulate that half the alkali atoms from one plane have exchanged sites, in the liquid state, with the halogens of the adjacent planes.

In the case of the fused metals of the cubic system, the values of σ_m derived from equation (1) are found to be slightly but consistently smaller than the experimental values; equation (2), with d derived from standard crystallographic planes, shows no improvement. The difference between the experimental and the calculated values can, perhaps, be accounted for on the basis that it represents the kinetic energy of the free electrons, which can only be possible if the density of the electrons in the surface layer is considerably smaller than that in the bulk of the liquid metal.

The above results show that just as the critical temperature is characterized by a zero value of the surface tension, the melting point may be defined as the temperature where the thermal energy of the translation of the molecules of a given surface becomes equal to its surface free energy. So long as the former is smaller, the surface preserves its characteristic solid form.

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Wave-Guide Systems with Negative Phase Velocities

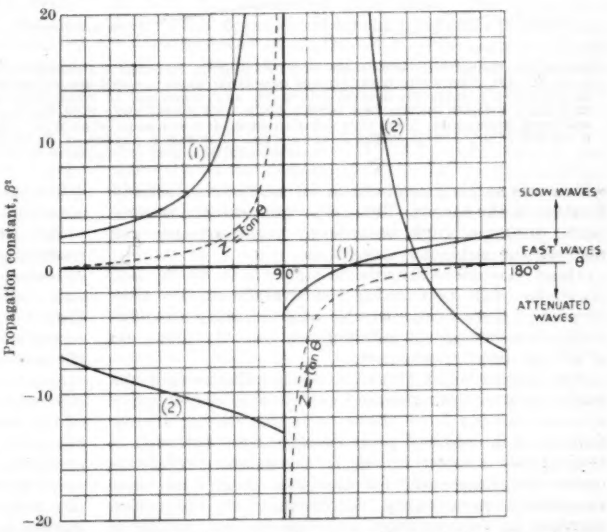
In all smooth wave-guides and many loaded wave-guides the phase velocity has the same sign as the energy velocity. Some systems having complex forms of loading have in the past been attributed with zero or even negative group-velocities, based on apparently anomalous dispersion curves. Such phenomena have been clouded by doubts about the conception of group velocity and its relationship to energy velocity. It has recently been shown that in a periodic structure with negligible attenuation, energy and group velocities are identical[1]. If a system is analysed in terms of the positive solution for phase velocity, a zero group-velocity indicates a form of resonance with zero net power flow, and a negative group-velocity indicates a negative net energy velocity. Since in any experiment the net energy velocity is taken to be positive, systems can be devised in which the phase-velocity is negative. Dispersion curves showing guide and air wave-lengths as ordinates and abscissæ must have a positive slope, and in these anomalous systems this requires a negative sign to be attributed to the measured guide wave-lengths. When interaction with charged particles is required, it is of supreme importance to determine the correct direction of the phase-velocity.

In such cases as the helix and the folded-strip transmission line, in which a wave with positive phase and energy velocities flows along the folded line, the fundamental wave (defined as that with longest wave-length), as observed by a charged particle travelling parallel to the axis of net flow of power, can have a genuinely negative phase-velocity. If a standing wave in any system is observed at discrete points by a square-law detector, the correctly drawn wave-length curves together with those obtained by adding $\pm 2n\pi$ phase change between successive points will show the correct phase velocities for a fundamental and its associated space harmonics, all with the same group-velocity equal to the total-energy velocity. Wave-length curves can, however, be drawn through such points with $\pm (2n + 1)\pi$ between successive points, and erroneous phase- and energy-velocities are then obtained.

There are, however, structures in which there can be no such confusion of space harmonics or wrongly drawn standing-wave curves, where the fundamental wave (defined as the mode which carries all the power when the periodic length is infinitely small) has a negative phase velocity.

A rectangular wave-guide which is loaded on one broad face with a reactive sheet propagates a longitudinal section wave (E_{11} H_{11}) with either positive or negative phase-velocity, depending upon whether the broad dimension is greater or less than $\lambda/2$ (λ being the wave-length in air). The way in which the square of the propagation constant (2π/guide wave-length) changes with the reactance of the sheet is shown in the diagram. To obtain a 'slow' wave with negative phase-velocity the reactive sheet must be capacitative, as compared with inductive for a positive phase-velocity.

The abnormal behaviour below H_{01} cut-off has been confirmed by two experimental arrangements: (1) a corrugated rectangular wave-guide in which the common broad dimension was less than $\lambda/2$ and the corrugations were made above H_{01} cut-off by loading with a dielectric material; (2) a rectangular wave-guide of broad dimension less than $\lambda/2$ loaded between the centres of its narrow faces by a slotted plate, the effective width of the slots being raised above $\lambda/2$ by thickening the plate along its centre line. In the latter system, the stored energy and power losses for a given electric field can be smaller than in the normal corrugated wave-guide, especially at very low phase-velocities, such as are required for travelling-wave tubes and for heavy-particle accelerators.



Typical behaviour of loaded rectangular wave-guides: (1) above H_{01} cut-off; (2) below H_{01} cut-off

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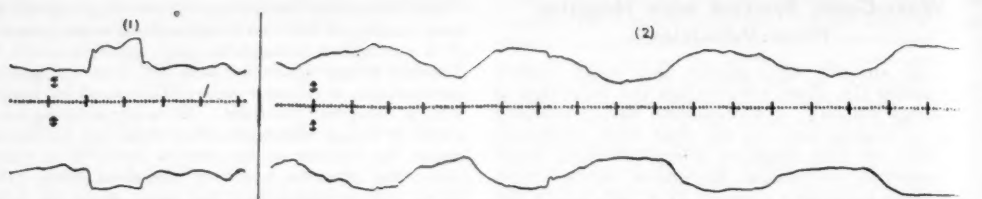
Binocular Eye Movements when Convergence is Subjectively Changed

The photoelectric corneal reflex method of recording eye movements of subjects in the sitting position[1] has been applied to the investigation of eye movements which occur when convergence is voluntarily changed. In these experiments, one fixation target only was used; this was a bright pin-hole, angular diameter 1′, distant 5½ ft. from the subject and situated on the visual axis of the right eye when this eye is looking straight ahead. The subject fixated this target binocularly, then increased his convergence by subjectively moving both eyes towards the nose through equal angles, the size of



(1) and (2), Respectively side-to-side and up-and-down binocular eye records for W. D. W.; (3), side-to-side binocular eye records for L. C. T.; (4), side-to-side binocular eye records for R. S. L. Right-eye records above the time line; towards the time line corresponds to movement towards the nose for side-to-side movements and to upwards for up-and-down movements. Left-eye records below the time line: towards the time line corresponds to movements away from the nose for side-to-side movements and to upwards for up-and-down movements. Time (increasing to right) I·····I represents 0·2 sec. For (1), (2) and (3), height of arrowed line represents a rotation of 20′. For (4), height of arrowed line represents a rotation of 5°, assuming the separation of the centre of curvature of the cornea and the centre of rotation of the eye is 5·3 mm.

which was at his discretion, and then resumed steady fixation of the target. This cycle was repeated several times during a single recording; the frequency was also at the subject's discretion.

Head movement records for subjects W. D. W. and R. S. L. while performing the experiment are very similar to their head records[1] while fixating steadily. Subjective change of convergence has, therefore, no effect on head movement.

For subject W. D. W., the records indicate that the main feature distinguishing side-to-side convergence eye movements from those occurring during steady fixation is a series of pairs of saccadic rotations: a typical pair is shown in Fig. 1. The saccadic rotations occur simultaneously for the two eyes; the first movement presumably corresponds to subjective increase in convergence, and the second, which is always in the opposite direction to the first, to subjective relaxation. The interval between members of a pair is fairly constant, average value 0·23 sec.; the interval between consecutive pairs, however, varies widely, the average being 1·7 sec. The average magnitude of each pair component is about 1° for both eyes. For about four-fifths of the pairs, the first movement is away from the nose for the right eye and towards the nose for the left; for the other fifth, the first movement is towards the nose for the right eye and away from the nose for the left. The objective change of convergence is therefore the difference of the left- and right-eye rotations; this difference is comparable with the experimental error. In the up-and-down direction, the records again show similar movements of the two eyes. These movements are, however, sinusoidal, of fairly constant frequency, average value 0·88 c.p.s.; the amplitude is comparable with that of the saccadic movements. A characteristic record is shown in Fig. 2. Records of simultaneous up-and-down movements of one eye and side-to-side movements of the other indicate that the first saccadic movement usually coincides with the start of the downward drift; the records confirm that not every wave cycle has a pair associated with it. Since W. D. W. endeavoured to repeat the movements at regular intervals, it is possible that the up-and-down movements are mainly responsible for his sensations of changing convergence. The saccadic side-to-side movements could serve to strengthen the sensations.

Records for subject L. C. T. have some points of resemblance to those for W. D. W.: pairs of saccadic movements again occur in the side-to-side direction and the movements of the two eyes are simultaneous. However, for L. C. T., the first movement is always towards the nose for the right eye and away from the nose for the left; the second movement is in the opposite direction. Moreover, sets of three saccadic movements occur as frequently as pairs; the direction of the first and second movements is the same as for the pairs, and the third movement is in the same direction as the first; Fig. 3 shows such a triplet. A third movement occurs when the second component has failed to return the eyes to the original fixation direction, either on account of inequality of the first and second components and/or of some movement during the interval between them. The average interval between the first and last components is $\frac{1}{2}$ sec.; that between consecutive sets of saccadic movements is $3\frac{1}{2}$ sec. The average magnitude of each component is about $\frac{1}{2}°$; the difference between corresponding right- and left-eye movements is again comparable with the experimental error and so, as in the case of W. D. W., it is impossible to say if there is any objective change of convergence. Since the up-and-down records for L. C. T. show no differences from those for steady fixation, it appears that his sensations of changing convergence arise solely from the saccadic side-to-side movements.

Convergence eye movements for R. S. L. are quite different from those for the other two subjects. His movements are so large that it was essential to use wedges[2] for their recording; even so, the larger movements are beyond the range of the apparatus. A typical side-to-side record of the smallest movements is shown in Fig. 4; it appears that the right eye first drifts towards the nose, through roughly 3°, in about $1\frac{1}{2}$ sec.; this presumably corresponds to increase of convergence. The drift is followed by a saccadic movement away from the nose of the same magnitude, presumably corresponding to relaxation of convergence. The eye then maintains a more or less steady fixation direction for about $1\frac{1}{2}$ sec., when the cycle starts again. The movements of the left

eye are greater than those of the right eye and are always too great to be recorded without distortion. However, some trends can be seen: corresponding to the drift of the right eye towards the nose is a drift of the left eye towards the nose of the same duration, and, approximately coincident with the jump of the right eye away from the nose, is a jump of the left eye towards the nose; this movement is, however, superimposed on a drift away from the nose. For R. S. L., therefore, the objective change in convergence is the sum of the left- and right-eye movements and so there is no doubt that it exists. The up-and-down records indicate movements in this direction also; these movements, however, follow no set pattern. So far as can be ascertained, their magnitude and frequency are similar to those of the side-to-side movements of the corresponding eye.

Since eye movements are determined by the tensions of the extra-ocular muscles, it should be possible to deduce information from the records about the energization, in activity, of these muscles. For example, when, as happens for W. D. W. and L. C. T., a decision to move an eye towards the nose results in a rotation away from the nose, it would seem that over-energization of the external rectus of the eye, relative to the internal rectus, is associated with the movement. Again, the objective difference in magnitude between the side-to-side, left- and right-eye movements for R. S. L. may arise from over-energization of the internal rectus of the left eye relative to the external rectus; this could also account for the flick towards the nose of the left eye, of which the subject is unaware. Moreover, when, as for W. D. W. and R. S. L., subjectively sideways rotations are, in fact, oblique, lack of balance between the superior and inferior recti and the obliques of the eyes in activity would seem to be indicated. The existence of extra-ocular muscle over-energization during eye movement may be of importance for the elucidation of many visual phenomena. It does not appear to have been previously reported, perhaps because the use of a second fixation target would cause suppression of most of the effects: it is hoped to investigate this point.

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Recovery of Human Red Cells after Prolonged Storage at — 79° C.

THE discovery[1] that glycerol largely prevents the death or disruption of living cells when subjected to temperatures well below the freezing point opened the way to the prolonged preservation of cells at temperatures where they might be said to be in a state of 'metabolic arrest'. It was found[2] that only slight hæmolysis results on thawing a blood – glycerol mixture which had been kept for a time at — 79° C. Afterwards, a procedure was devised[3] whereby such a thawed blood – glycerol mixture could be freed of glycerol by dialysis and the bulk of the red cells recovered in normal condition. Transfusion studies in rabbits[4] and humans[5] have established that red cells recovered after storage for short periods at — 79° C. are viable. The purpose of the present communication is to report the results of further experiments *in vitro* in which human red cells have been stored at — 79° C. for periods up to nine months.

The procedure used is essentially the same as that previously described[3]. In the present experiments the desired quantity of blood (containing acid–citrate–dextrose anticoagulant) or concentrated red-cell suspension was mixed with an equal volume of glycerol solution (30 gm. glycerol and 0·9 gm. sodium chloride per 100 ml.) and 10 ml. of the mixture was transferred to each of a number of glass tubes. The tubes were sealed, and approximately one hour after mixing they were immersed in the alcohol – solid carbon dioxide bath in which they were stored. The storage baths were kept in large Dewar flasks which were liberally supplied with solid carbon dioxide, so that additions were required only two or three times weekly. The storage temperature should not be permitted to rise more than a few degrees above — 79° C., since storage above — 70° C. is decidedly less favourable to the survival of the red cells. No attempt was made to prevent bacterial contamination. Samples were thawed in a bath at 37° C., the glycerol removed from the mixture by relatively slow dialysis, and the cells were washed with cold saline. The cells were then suspended in plasma to a total volume of 5 ml., that is, equal to the volume of the original blood sample. Estimates of the recovery of red cells were made from cell counts or hæmoglobin measurements of both the original blood sample and the suspension of recovered cells.

The recoveries of cells after storage varied somewhat from one batch of blood to another, but were fairly uniform in most cases. After one day of storage, about 90 per cent of the cells were recovered. After one month the recovery dropped to about 80 per cent. Thereafter, there was only a very slow drop in recovery, so that after six months it was about 70 per cent, and at nine months had dropped very little further. Since the metabolic activity of cells must be negligible at — 79° C., this slow loss of cells is very likely due to a slow physical transition in the solid mixture. The freezing process used in these experiments is not an ultra-rapid one and there is no doubt that ice crystals form in the mixture[6]. Whether ice crystals are, in fact, formed within the cells is not established; but there seems to be little reason to suppose that they are not formed. The mechanism whereby glycerol and some related compounds prevent hæmolysis on freezing is now being studied, and it is hoped to shed some light on the nature of the changes which cause destruction of cells during storage.

Although the present study demonstrates that red cells can be recovered apparently intact after long periods of storage at — 79° C., it cannot be assumed that their viability is unimpaired. The usefulness of the present process in the field of blood transfusion depends upon demonstrating that the recovered red cells survive satisfactorily in human subjects after transfusion. Experiments are now in progress to investigate this point.

If it can be demonstrated that the antigenic properties of the red cells are unimpaired after long storage at — 79° C., this method will doubtless be useful

in the laboratory as a means of preserving red cells of rare blood groups.

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Toxicity of Aureomycin to Guinea Pigs

Since the original studies of Stokstad and co-workers[1], the growth-promoting effect of aureomycin has been established with several species of animals. So far as we know there are, however, no reports about the effect of aureomycin on guinea pigs. We have used aureomycin in investigations dealing with the synthesis of vitamins in the intestines of rats and guinea pigs. In these experiments it was found that the effect of aureomycin on guinea pigs is quite different from that observed with rats. The same proportional dose which has had a growth-promoting effect on rats appears to be very toxic to guinea pigs.

The diet used for guinea pigs in our experiments consisted of: ground clover – timothy hay 20 per cent, oatmeal 32 per cent, rye-meal 22 per cent, casein 12 per cent, margarine 3·8 per cent, salt mixture (containing 1,000 gm. sodium chloride, 1,000 gm. calcium lactate, 30 gm. ferric citrate, 10 gm. manganese sulphate, 2 gm. copper sulphate and 0·2 gm. potassium iodide) 1·6 per cent, dried brewers' yeast 4 per cent, wheat germs 4 per cent and cod liver oil 0·2 per cent. Vitamin C dissolved in sucrose solution was fed with individual pipettes about 25 mgm. every other day. Crystalline aureomycin hydrochloride was fed at the level of 100 mgm. per kilogram of ration.

The diet containing aureomycin was fed at first to nine guinea pigs weighing 160–210 gm. All the animals began to lose weight on the second day of the experiment, and six out of nine died in ten days. The remaining three survived and even gained weight after the initial loss of weight; but within five to six weeks two of these animals died. In ten control animals not receiving aureomycin, no disturbances were noticed.

In further experiments the aureomycin diet was fed to six adult guinea pigs of average weight 900 gm. All these animals lost weight from the first day of feeding and died in seven to fifteen days. The average loss in weight was 23 gm. a day. A similar loss of weight resulting in death in ten days was observed when aureomycin was injected subcutaneously at the level of 1 mgm. per day to four other adult animals.

Feed consumption of the animals receiving aureomycin either orally or subcutaneously fell practically to zero soon after the administration of the drug was started. Water consumption, also, was markedly reduced.

A review of the literature shows that aureomycin has been found earlier to be toxic to some other animals, including mice[2], lambs[3], steers[4] and dogs[5]. The toxicity of penicillin to guinea pigs has recently been shown[6]. Reasons for these toxic effects have not been clearly established. It has been assumed that harmful effects on the intestinal flora might play an important part. It is scarcely likely, however, that the rapid effect found in our experiments could be due to an unfavourable change in the intestinal flora. The results rather point to a more direct toxic effect of aureomycin on the metabolism of the animal. The suggestion of Loomis[7] that the toxicity of aureomycin is derived from its ability to inhibit aerobic phosphorylation deserves further consideration in this connexion.

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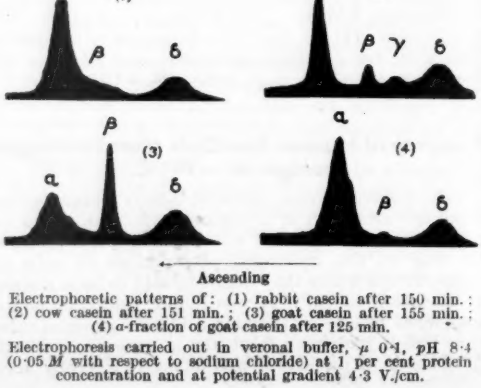
A Comparison of the Electrophoretic Patterns of Cow, Goat and Rabbit Casein

During the course of some work involving the fractionation of proteins from goat milk, we have found a marked difference between the electrophoretic patterns obtained with goat-milk and cow-milk casein.

The respective patterns are shown in the accompanying diagram (the usual convention of referring to the components as α, β and γ in order of their decreasing mobility is adopted). The pattern for cow casein is very similar to that obtained under identical conditions by Hipp, Groves, Carter and McMeekin[1], whereas that obtained for goat casein under the same



Electrophoretic patterns of: (1) rabbit casein after 150 min.; (2) cow casein after 151 min.; (3) goat casein after 155 min.; (4) α-fraction of goat casein after 125 min.

Electrophoresis carried out in veronal buffer, μ 0·1, pH 8·4 (0·05 *M* with respect to sodium chloride) at 1 per cent protein concentration and at potential gradient 4·3 V./cm.

conditions shows a complete absence of γ- and a very different distribution in the relative amounts of α- and β-components. In addition, the α-component in the goat casein appears to be less homogeneous than that in the cow. (Further electrophoretic studies on goat casein at higher concentrations in phosphate buffer have shown the presence of a γ-casein which only separates from the salt boundary after long periods.)

The relative amounts of the α- and β-components calculated from the electrophoretic patterns are shown in the table. The distribution found for cow casein is similar to that reported by Hipp *et al.*[1], whereas for goat casein there is approximately 50 per cent of each component.

DISTRIBUTION AND MOBILITY OF COMPONENTS OF CASEIN FROM DIFFERENT ANIMALS

Mobilities (μ) are expressed in $cm.^2 volt^{-1} sec.^{-1}$ and distribution in per cent total protein. All measurements were made on descending boundaries

Animal	α-Component $\mu \times 10^5$	per cent	β-Component $\mu \times 10^5$	per cent
Cow	5·9	84	3·1	16
Goat, unfractionated	6·7	49	3·4	51
Goat, fractionated	6·4	—	—	—
Rabbit	5·6	89	1·7	11

We have also studied the electrophoretic pattern of rabbit-milk casein. Under the same experimental conditions, this is different from either goat- or cow-milk casein, and as is shown in the electrophoretic pattern at *p*H 8·4 it appears to contain very much less of the β-component than does cow or goat casein.

In considering the possible relationship existing between the components of casein from different sources, their electrophoretic mobilities are of interest. These, as determined under identical conditions, are shown in the table. The results indicate that the α-components have different mobilities according to the milk from which the casein was obtained. Mellander[2], in a comparison of the electrophoretic patterns obtained with human-milk casein and cow-milk casein, also found a wide divergence between the mobilities of the components. A change in mobility sometimes occurs when a protein is purified. However, it seems unlikely that the difference in the mobilities of the α-components in the present case could be due entirely to differences in the relative amounts of the various components, for when the amount of the β-component was reduced to a very low level by fractionation of goat casein (see diagram) (Warner[3]), the mobility of the α-component was only slightly reduced. Thus the electrophoretic mobilities would suggest a difference between the various α-components. However, the method described by Warner[3] for the fractionation of cow casein proved equally successful when applied to goat casein, so that the α- and β-components of these two caseins would seem to have similar solubilities and isoelectric points.

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A Regulatory Mechanism in the Posterior Ciliary Arteries of the Dog

SUBENDOTHELIAL cushions consisting of longitudinally running smooth muscle fibres inside the circular muscle coat have now been described in the arteries of many organs under the names of 'intimapolster', 'coussinets', etc.; but the only report of their presence in the arteries of the eye appears to be that of Gallas[1], who found them in the long, and less regularly the short, posterior ciliary arteries of man.

The retinal blood supply in the dog is by means of branches of the short posterior ciliary arteries; it is doubtful if there is a central artery of the retina in this animal[2]. In a study of serial sections through six dogs' eyes I have found well-marked cushions in all those branches of the ciliary arteries which give rise to a retinal branch (Fig. 1). The cushions first appear in the arteries at the point where they commence to run forward through the sclera, and they cease soon after the vessel has turned into the choroid; that is, the retinal branch is always given off from the cushioned portion of the artery. Some smaller branches of the ciliary arteries run more obliquely through the sclera and do not give a retinal branch. These never contain cushions.

The relation of the cushions to the internal elastic lamina is variable. In some cases the cushions are entirely inside the lamina, which continues uninterruptedly; in others, the lamina becomes split up into fine elastic fibres which run in between the muscle cells. Occasionally, both these appearances may be seen along the length of the same cushion. In some cases, at the point where the vessel bends round into the choroid and gives off its retinal branch, the cushions have a valve-like disposition (see Fig. 2).

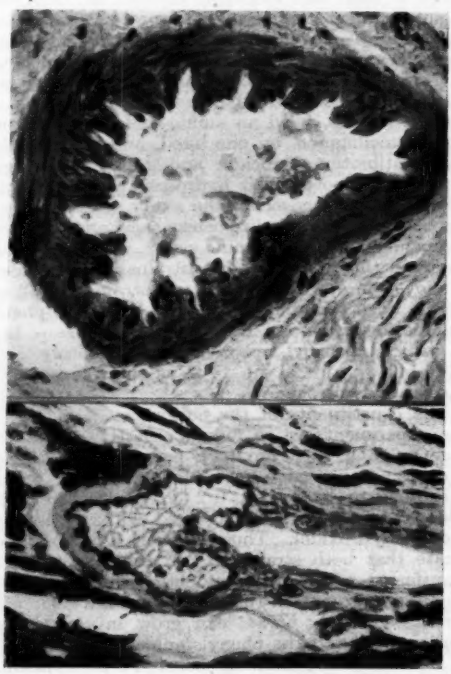

Fig. 1. Hæmatoxylin, eosin. × 375
Fig. 2. Weigert's elastin, alum carmine. × 510

The retinal branch, cut transversely, is filled with blood, whereas the choroidal branch, cut longitudinally, is empty.

The function of subendothelial cushions is usually described as regulatory; that is, when the musculature of the vessel wall contracts, the swelling of the cushions helps to occlude the lumen. If this be true, the function of the cushions I have described may well be to diminish the blood flow to the choroid, while at the same time their disposition is such that they may also help to maintain the retinal circulation by holding the mouths of the thin-walled retinal vessels open.

The presence of similar cushions would presumably occur in the eyes of other animals in which the retinal supply is entirely derived from the ciliary arteries. This point is now being investigated, and a more detailed description of the cushions will be published elsewhere.

I should like to thank Dr. F. Jacoby for much helpful advice and criticism, and Mr. A. Welch for taking the photomicrographs.

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Hydrolysis and Metabolism by Soil Bacteria of Benzoyl-D-Phenylalanine

Since Kögl and Erxleben showed, in 1939, that D-glutamic acid can be isolated from cancerous tissue, D-peptidases have been the subject of many researches. Kögl and Erxleben's demonstration seems to have particular interest, when considered together with the fact that penicillins, on acid hydrolysis, yield an amino-acid of D-configuration, penicillamine, on one hand, and the fact that both antibiotics, tyrocidin and gramicidin *S*, give D-phenylalanine as their hydrolysis product, on the other. While engaged in the study of capability of soil bacteria to metabolize benzoic acid and its related compounds, and some amino-acids[1], we have recently observed that, of thirty-four strains of soil bacteria employed in our experiment, two strains, *KT*82 and *KT*83, have the ability to utilize benzoyl-D-phenylalanine (melting point 139°–140°; $[\alpha]_D^{13} = -14{\cdot}9$) as well as benzoyl-L-phenylalanine (melting point 139°–140°; $[\alpha]_D^{13} = +14{\cdot}8$) as the sole source of carbon and nitrogen.

The constituents of the culture medium used in the experiment are as follows: K_2HPO_4, 0·1 gm.; $MgSO_4.7H_2O$, 0·05 gm.; 1 per cent $CaCl_2.6H_2O$, 2 drops; 1 per cent $FeCl_3.6H_2O$, 1 drop; organic substance to be tested, 0·2 gm.; distilled water, 100 c.c.; *p*H 7·0–7·2 (adjusted with 10 per cent sodium hydroxide). Thus, we were able to demonstrate that both strains, *KT*82 and *KT*83, can be transferred without any reduction in their rate of population growth in the above medium. One other strain, however, *KT*84, can grow in the medium containing benzoyl-L-phenylalanine, but not at all in the medium containing benzoyl-D-phenylalanine.

The three above-mentioned soil-bacteria strains were then tested for their hydrolytic activity upon benzoyl-D-phenylalanine as follows: 897 mgm. (1/300 *M*) benzoyl-D-phenylalanine suspended in 100 c.c. of distilled water was dissolved by the dropwise addition of 10 per cent sodium hydroxide, until the *p*H was 7·0–7·2. After dispersing the bacterial mass grown on an agar slant at 25° C. for two days (corresponding to *c.* 300 mgm. on a dry weight basis) and 2 c.c. of toluene in 100 c.c. of the benzoyl-D-phenylalanine solution, the *p*H was again adjusted to 7·0–7·2, and the mixture thus obtained was allowed to digest at 37° C. After seven days, the mixture, after cooling, was acidified with dilute hydrochloric acid to Congo red. The precipitate was treated with petroleum ether (boiling point 30°–65° C.), and evaporation of the extract yielded a crude product which after further refining with petroleum ether was identified as benzoic acid by the mixed melting point. The yields of benzoic acid were 33 mgm. (8 per cent) for *KT*82 and 137 mgm. (34 per cent) for *KT*83. No trace of benzoic acid was found when a mixture of benzoyl-D-phenylalanine solution, heat-killed *KT*82 and toluene, was used.

It is of interest that the *KT*84 strain differed from *KT*82 or *KT*83 in failing to hydrolyse benzoyl-D-phenylalanine.

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Fungi inhibiting Growth of the Crown-rot Disease Fungus *Sclerotium delphinii* Welch

Sclerotium delphinii Welch is recognized as a highly destructive pathogen of a large number of vegetables and ornamental plants. Efforts during the past twenty-five years to develop practical control of this fungus have met with failure. Some investigators reported a slight benefit with chemicals, but the control achieved was far from satisfactory. Chemical tests by Davey and Leach in 1941[1], on a closely related organism, *Sclerotium rolfsii*, revealed that, of the seventeen water-soluble chemicals tested, only formalin at dilutions of 1 : 100 and applied at 3 gallons per sq. ft. of soil surface was effective. More recently, chemicals were also tried by Thomas Laskaris, while working on diseases of delphinium at the New York Botanical Garden. Because these and other workers were unsuccessful in finding a chemical control for this highly destructive fungus, an attempt has therefore been made, at the suggestion of Dr. P. P. Pirone, plant pathologist of the New York Botanical Garden, to achieve control by biological methods.

The early work involved attempts to infect sclerotia of *S. delphinii* with the fungus *Coniothyrium minitans* reported by W. A. Campbell[2] in 1947 as a parasite of sclerotia of *Sclerotinia sclerotiorum* and *Sclerotinia minor*. *C. minitans* was found incapable of infecting sclerotia of *S. delphinii*.

The second phase was a search for fungus and bacterial parasites of sclerotia of *S. delphinii*. Hundreds of sclerotia occurring in naturally infested

soils were plated out in the course of several months; but in no case was a parasitic agent found on or in any of these.

The third and major phase of the problem was more fruitful. This involved *in vitro* testing of the effects of a large number of fungi and some bacteria collected from various sources on *S. delphinii*. Some of the fungi were isolated from soils collected in Baltimore, Maryland; Madison, Wisconsin; the Pine Barrens of New Jersey; the Fordham University Campus and the grounds of the New York Botanical Garden. In addition to these sources, some fungi were secured from other investigators and the American Type Culture Collection, Washington, D.C.

Of the forty fungi tested, three were found to have a strong inhibitory effect *in vitro* upon the mycelium of *S. delphinii* when grown on 'Difco' potato dextrose agar. This inhibitory activity was evident for sixty or more days, or until the medium dried completely. These tests were repeated more than fifty times with the same results.

The antagonistic effects were studied by planting both the test fungus and *S. delphinii* at different locations in 'Petri' dishes containing potato dextrose agar. The method most commonly used was to place the test organism and the disease-producing fungus at opposite sides of each dish. In some plates both plantings were made on the same day; in others, because of the rapid growth of *S. delphinii*, the inhibitory fungus was planted five to six days earlier. All plates were incubated at 70–80° F. and examined periodically. In all these cases the reaction was evident after a week (Figs. 1 and 2).

Two of the fungi, species of *Penicillium*, showed greater inhibition than the third, which appears to belong to the Fungi Imperfecti.

Dr. Kenneth B. Raper, of the Northern Regional Research Laboratories, Peoria, Illinois, has kindly determined one species of *Penicillium* as a strain of *P. brevi-compactum* and the second as a strain of *P. charlesii*. *P. brevi-compactum* and the imperfect fungus were isolated from soil collected on the Fordham University Campus, whereas *P. charlesii* was obtained from soil collected at Madison, Wisconsin.

The practical utilization of these penicillia as agents in combating the crown-rot fungus disease is now being studied. For this purpose the penicillia are grown in large quantities in Czapek–Dox medium for seventeen to eighteen days on a shaker, then filtered. The filtrate in varying amounts is then poured into standard greenhouse flats containing soil which was artificially infested with sclerotia of *S. delphinii* two to three weeks earlier. Controls are set up using uninoculated Czapek–Dox medium in other flats of similarly infested soil. A few days after adding the filtrate, *Ajuga reptans* and *Mazus reptans*, two plants extremely susceptible to *S. delphinii*, are planted in all flats to determine whether they will survive or succumb. All these experiments are being conducted in the greenhouse of the New York Botanical Garden at day temperatures ranging from 70° to 80° F. and at night from 50° to 55° F. Since these experiments have only recently been set up, it is too early to draw conclusions on the effectiveness of controlling *S. delphinii* by this method.

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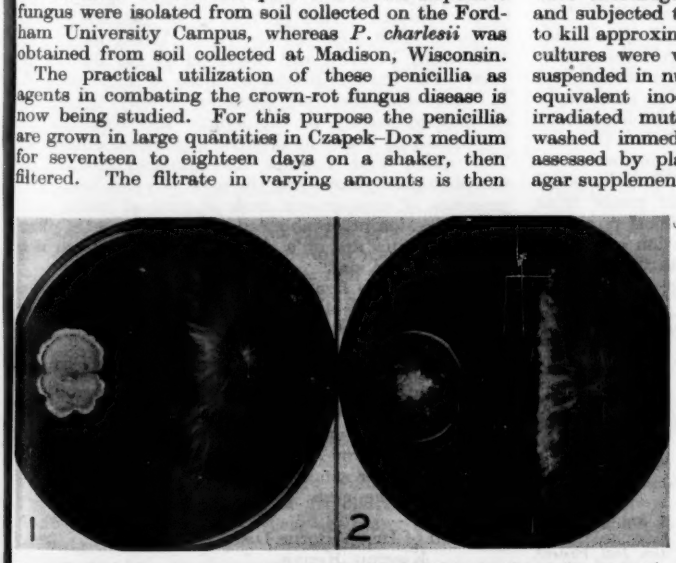

Fig. 1. *Penicillium brevi-compactum* (left) exerting strong inhibitory action on the crown-rot fungus *Sclerotium delphinii*, which has covered half the 'Petri' dish

Fig. 2. *Penicillium charlesii* (left) inhibiting the mycelial development of *Sclerotium delphinii*

Genetic Recombination in *Bact. coli* K12: Analysis of the Stimulating Effect of Ultra-violet Light

The recent demonstration[1] of the clear-cut differential effect of streptomycin on the fertility of the equally sensitive *Bact. coli K*12 mutant strains 58–161 and *W*677, which show genetic recombination, suggested that analysis of the stimulating effect on recombination of small doses of ultra-violet light, reported by Haas *et al.*[2], might yield interesting results.

Logarithmic-phase broth cultures of each mutant were centrifuged, resuspended in buffer at *p*H 7·2 and subjected to doses of ultra-violet light sufficient to kill approximately 50 per cent of cells. Irradiated cultures were washed to remove peroxides and resuspended in nutrient broth at 37° for an hour. An equivalent inoculum of the complementary, unirradiated mutant was then added, the mixture washed immediately and the recombination-rate assessed by plating standard volumes on minimal agar supplemented with aneurin.

Irradiation of *W*677 consistently produced a fall in recombination-rate, roughly proportional to the drop in viable count following exposure, when compared with that shown by unirradiated but otherwise similar mixtures. Irradiation of 58–161, on the other hand, regularly yielded a five- to twenty-fold (and sometimes much greater) rise in recombination-rate, despite a fall in viable count comparable to that shown by *W*677. When the irradiated mutants were plated separately, no prototroph colonies appeared. The enhancement of the fertility of 58–161 by ultra-violet light increased with dosage to a maximum when the viable count had been reduced by about

75 per cent, further increase in dosage producing a progressive fall in the prototroph count.

The stimulation of recombination by ultra-violet light was even more markedly displayed if cultures of 58–161 which had been irradiated and incubated in broth at 37° for an hour were sterilized by the addition of streptomycin and the broth then seeded with *W*677/*S*^{r}, the recombination-rate being assessed after overnight incubation. When *W*677/*S*^{r} was grown in the supernatant fluid from centrifugates of such irradiated and streptomycin-treated cultures, however, no prototrophs arose. This demonstrates, in a more convincing manner than by filtration, the dependence of recombination on the presence of the bacterial cells themselves.

For the development of enhanced fertility, incubation in nutrient broth following irradiation is essential. Cultures of 58–161 which were washed and plated, together with the complementary mutant, on minimal agar immediately after irradiation, showed a *decrease* in recombination-rate, although markedly increased rates were given by aliquots of the same irradiated suspensions after incubation in broth. Again, no enhancement occurs if irradiated cultures are incubated in fluid synthetic medium, adequate to support full growth of 58–161, instead of in broth. Following irradiation and incubation in horse meat-infusion broth at 37°, the fertility of 58–161 rose steadily to a maximum after incubation for one hour, and thereafter fell slowly to about half the maximum after three hours. Throughout this period there was no significant increase or decrease in the viable count, but the cells increased markedly in length.

The differential action of streptomycin on the fertility of *K*12 mutants was interpreted[1] as suggesting the unidirectional transfer of genetic material from 58–161 (gene donator) to *W*677 (gene acceptor), the unimpaired fertility of the former being attributed to extrusion by the living cell of a metabolically inert gamete (or gametes) which adhered to the cell wall, so that the subsequent role of the cell in recombination was that of a passive carrier of its genetic elements, a function independent of viability. The restriction of the stimulating effect of ultra-violet light to the 'gene donator' strain confirms the qualitative distinction between the two mutants and suggests that the effect may be due to increase in the proportion of 58–161 cells which extrude potent gametes. The apparent parallelism between the conditions required for optimal ultra-violet enhancement of recombination and those described by other workers[2–5] for the liberation of lytic phage from lysogenic strains of bacteria (Lwoff effect) points to the possibility, however, that stimulation of 58–161 fertility may be only secondary to phage liberation, since both 58–161 and *W*677 are lysogenic and carry *lambda* phage.

A detailed account of this and preceding work will be published elsewhere.

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Phoretic Association between Simuliidæ and Crabs

The discovery of phoretic associations between *Afronurus* and *Simulium* species and between the early stages of *Simulium neavei* and freshwater crabs has been reported in *Nature*[1]. I was then under the impression that *S. neavei* was the only species which lived in a state of phoresis with *Potamon niloticus* (the crab concerned); but subsequent surveys have revealed that the earlier stages of at least two other species participate in this association.

In May 1950, crab surveys were instituted in the Kakamega District, North Nyanza, Kenya, with the view of establishing the limits of the *S. neavei* focus known to exist there. This was necessary prior to embarking on a scheme of eradication of this important vector of onchocerciasis. It was expected that phoresis would cease to occur rather abruptly and that the limits would not be far distant from the haunts frequented by the adults—always in dense forest or in thickly wooded streams and rivers. It was with some surprise, therefore, that phoresis was observed in open rivers many miles away. The larvæ and pupæ closely resembled those of *S. neavei*, and some confusion was experienced. It was not until adults had been bred that it was realized that what was at first thought to be a new species was obtained. It proved to be *S. nyasalandicum*, originally collected by Neave on Mount Mlanje, Nyasaland, in 1914, and described by De Meillon in 1930. The most obvious macroscopic differences are the presence of pale areas on the legs of males and females as opposed to uniformly dark legs in *S. neavei*, and the increased number of golden scales on the tibiæ of the males. The structure of the male genitalia is of a distinctive pattern.

Later on, it was noticed that larvæ and pupæ existed in the exhalant passage of the bronchial chamber of some of the crabs. This was thought to be an accidental ingression; but when imagines were bred it was quite obvious that yet another species had been obtained. This proved to be identical with *S. woodi*, first collected by R. C. Wood at Cholo, Nyasaland, in 1917, and described by De Meillon in 1930. The pupa is similar to those of *S. neavei* and *S. nyasalandicum*, but exhibits certain divergent characters, mainly in the length and structure of the breathing filaments and the abdominal armature. The males and females also possess distinctive morphological characters, the most obvious being the presence of conspicuous dark abdominal bands and the possession of pronounced tarsal claw teeth. The male genitalia are of a distinctive pattern and are much larger in size.

Although the females of both species have been described by De Meillon, the males and the earlier stages have yet to be, and this will be done in the near future.

I wish to thank Dr. T. Farnworth Anderson, director of medical services, Kenya, for permission to publish this communication, and Mr. H. Goiny, Kenya Medical Department, who first noticed—what must be considered a singularly unique observation—namely, the presence of *S. woodi* in the exhalant passage of the crab.

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Application of the Principles of Phylembryogenesis to the Protista

THE real relation between ontogeny and the adult stages of ancestors (phylogeny) in multicellular organisms (Metazoa and Metaphyta) is now firmly established in the sense that ontogeny is not an abbreviated or modified phylogeny, that is, the stages of development of an individual do not correspond to the adult forms of the ancestors, as was required by the so-called biogenetic law or theory of recapitulation propounded by Ernst Haeckel. All stages of ontogeny are subject to hereditary changes of evolutionary character. Moreover, the greater changes achieved in the early stages of ontogeny, resulting in pædomorphosis and neoteny, appear to be the most important from the point of view of large-scale evolution (macro-evolution). The changes brought about in later stages of ontogeny, resulting in gerontomorphosis, have an adaptive and specialized significance (Garstang, Sewertzoff, de Beer, Hadži).

The question may be asked whether these principles can be applied to the ancestors of the multicellular organisms, that is, to the Protista. In these there is no ontogeny but only a succession of different generations during the life-cycle.

In attempting to answer this question, we have first to compare the life-cycles of Protista with the ontogenies of multicellular forms, in order to establish which phases of the life-cycle of the former correspond to which stages in the individual development of the latter. Next, we must discover whether in the Protista hereditary changes of an evolutionary character make their appearance at all phases of the life-cycle. Analysis and comparison of a few examples selected from among Protista and multicellular forms have revealed which are the corresponding phases in the life-cycle of Protista and in the ontogenies of multicellular organisms.

In the Protista, the chief phases (some of which also comprise sub-phases) take the form of generations, such as the vegetative, progamic, gametic and metagamic generations. The most important phases in the Metazoa are the vegetative and the metagametic (= ontogenetic) phases, while the progamic phase is always enclosed within the gonad. The gametic phase is either free, as in most Protista, and associated with external fertilization, with the exception of the Infusoria; or it remains enclosed within the vegetative phase and is associated with internal fertilization.

Comparisons of the life-cycles of various types of Protista have shown with certainty that evolutionary changes have occurred in all phases or stages of the life-cycles. Larger and more rapid changes involve whole generations, while smaller and slower changes, having the character of adaptations, may be effected within single phases or generations. It therefore seems legitimate to apply the modalities of the development of multicellular organisms (phylembryogenesis of Sewertzoff, pædomorphosis of Garstang, gerontomorphosis of de Beer) to the conditions in the Protista.

In order to illustrate this idea, I propose to take the example of the Euciliate Infusoria as representatives of the Protozoa. Mention should first be made of *Paramecium*, with its rather complex life-cycle. Between the ciliates and the flagellates, which are doubtless their ancestors, there are many differences unbridged to-day by any intermediate forms. The switch-over to a single generation, namely, the vegetative generation, must have occurred by means of a rapid evolutionary change in the history of the ciliates. The remaining three generations, namely, the progamic, gametic and metagamic generations, in the ciliates are enclosed within the vegetative generation and therefore no longer appear as separate entities. Furthermore, the ciliates have become hermaphrodite.

Even the metagamic phase, which corresponds to the ontogeny of multicellular forms, has in ciliates undergone deep change and remains enclosed within the vegetative phase. This metagamic phase is, in fact, changed in so far as the meganucleus of the vegetative phase disappears. During the transition from the Protista to the multicellular condition, the gametic phase became independent and free again as a result of cellularization.

My second example, which I should go so far as to call a case of pædomorphosis, is to be found among the Folliculinidæ (Infusoria, Heterotricha). Here the entire sexual part of the life-cycle (progamic, gametic and metagamic phases) has vanished, and a new, free, vegetative phase has appeared instead, because the old vegetative phase or generation has become sessile.

It is probable that bacteria and viruses may be found to provide examples among the Protista of the applicability of these principles. In such cases, the macro-evolutionary changes would be of a retrogressive character associated with the specialization in adaptation to saprobiotic and parasitic modes of life. The theory of phylembryogenesis might in a general way be applied to viruses and throw new light on their nature and origin. The opinions which microbiologists hold on bacteria and viruses are very divergent; but on the interpretation here suggested, it is possible that viruses may be ascribed to the proper position in the natural system. By comparing the life-cycle, we arrive at the conclusion that viruses were evolved from spore-forming bacteria, in adaptation to conditions of extreme parasitism within the cytoplasm of foreign cells.

In this manner, viruses would reach the level of organization of bacterial spores, decreasing the size of their bodies and simplifying their structure and metabolism. The loss of the entire sexual phase would not in any way invalidate the applicability of the principles and modalities of phylembryogenesis.

I believe that further application of these principles to cases in the Protista will have results as fruitful for the study of Protista as they have already had for multicellular forms.

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'Spiral' Roots in Agar Cultures of *Marsilea*

THE general conditions for the preparation and growth of sterile cultures of the heterosporous fern *Marsilea* have already been described[1-3]. It was shown[3] that, with glucose as carbon source, much better growth was obtained in liquid than on agar media. During further work on this subject an unusual phenomenon was observed in the root system of the agar cultures.

As shown in Figs. 1*a* and *b* and Fig. 2, many roots have pronounced helical ('spiral') growth especially in the more slender regions nearer the tips. In most of the roots the spiral follows the same course, that is, anticlockwise towards the apex, although a few roots have a clockwise spiral. An occasional root, for example, the conspicuous spiral root of Fig. 1*b*,

even shows a change in the direction of the spiral in different parts of its length. Fig. 1*a* is of an untouched culture with the roots still in agar. In Figs. 1*b* and *c* and Fig. 2, the agar has been carefully removed after first soaking in water.

Whatever the ultimate cause of this phenomenon, it is clearly connected with the physical properties of the agar medium. Thus, on a liquid medium of identical composition except for the omission of agar, the roots are remarkably straight. In agar media, replacement of the glucose by sucrose results in more vigorous plants with much stouter roots, and as shown in Fig. 1*c* the roots are either straight or with greatly attenuated spirals. It seems that the strength of the roots is important, as even in the glucose agar, one finds differences according to the vigour of the plants. In the cultures with a feeble root system the coils of the spiral are closer than in cultures with better-developed roots.

In view of these facts, it seems probable that the spiral roots described have been produced by a failure of the roots to overcome the resistance offered by the agar to the straightening process which normally follows the circumnutation of the apex. The classical work of Darwin[4], first published in 1880, showed that circumnutation is found in all the organs of every plant while they continue to grow. By the use of smoked-glass plates he was able to show that the root tips of the several plants investigated followed a more or less spiral course. A reference to his figures shows that the dimensions of the spirals were of the same order as those of the spirals observed in the present work.

So far as I am aware, the formation of spiral roots by plants growing in agar has not been recorded previously. The plants used in other work probably had roots which were strong enough to overcome the resistance of the agar. By using increased concentrations of agar, spiral roots might arise even in these cases. Studies of root growth in various media containing different concentrations of agar should yield new information on circumnutation, which appears to have received little attention in recent times[5].

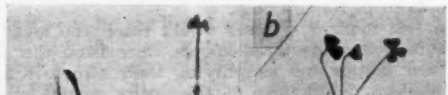

Fig. 1. *Marsilea drummondii* A.Br. (*a*) Culture after 14 weeks on medium containing 2 per cent glucose and 0·75 per cent agar (×3); (*b*) the same culture after 17 weeks. Agar removed (nat. size); (*c*) culture after 17 weeks on medium containing 2 per cent sucrose and 0·75 per cent agar. Agar removed (nat. size)

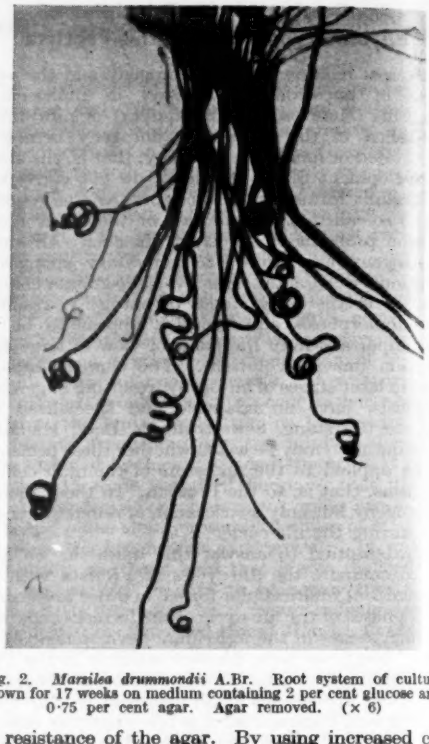

Fig. 2. *Marsilea drummondii* A.Br. Root system of culture grown for 17 weeks on medium containing 2 per cent glucose and 0·75 per cent agar. Agar removed. (× 6)

I am indebted to Mr. Ernest Ashby for the photographs in Figs. 1 and 2.

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May 8.

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Role of the Sulphydryl Group in the Formation of Alkaline Protein Gels

Commenting on an account[1] from this laboratory of the gelation of alkaline casein dispersions, Wormell[2] has suggested that the sulphydryl group is the specific one concerned in gelation and that its oxidation to the disulphide bond provides the most likely cross-linkage. In work as yet unpublished, we have also considered the possibility of non-methionine sulphur being involved in gelation. The results shown in Table 1 represent the amounts of alkali-labile sulphur liberated from the system lactic casein–sodium hydroxide–water at 25° C. when the ratio of air-dry casein to water is 2 : 5. At the

Table 1. SULPHIDE LIBERATED
(expressed as gm. cyst(e)ine/100 gm. casein* for comparison with data of Table 2)

pH Series (5 hr.)			Time series (pH 13·4)	
Treatment		Sulphide liberated	Period of reaction (hr.)	Sulphide liberated
NaOH concentration†	pH attained			
4·0	9·7	0·011	0	0·005
5·0	10·7	0·012		
6·0	11·4	0·012	0·5	0·020
6·3	12·1	0·011		
6·8	12·3	0·022	1	0·020
7·0	12·5	0·023	2	0·027
8·0	12·9	0·026	3	0·022
9·7	13·3	0·035	4	0·032
11·9	13·5	0·039	5	0·034
15·8	13·7	0·039	24	0·000
19·8	13·9	0·040	(gel)	

* Air-dry, containing 9·6 per cent moisture and 2·3 per cent ash.
† In gm./100 gm. casein, as above*.

end of the period of reaction, the glues were dispersed in their own volume of water and 1 *N* hydrochloric acid added, in excess of that required for precipitation. The appearance of the protein precipitated after treatment at high *p*H was distinctly fibrous; milder treatments yielded flocculent precipitates. The hydrogen sulphide evolved was passed through *N*/10 iodine solution, the protein dispersions being boiled until a negative sulphide test was given by lead acetate. The liberated sulphur was determined by back-titration against *N*/100 sodium thiosulphate.

can be satisfactorily accounted for as cystine plus cysteine only up to *c.* *p*H 12; above this, the deficiency rises sharply up to *p*H 13·5 and thereupon remains fairly constant. The *p*H range 12–13·5 is also critical for liberated sulphur (Table 1); but it is clear that the values for sulphur liberated as sulphide are far too small to account for the cystine deficiencies.

In view of the paucity of cystine residues in casein, it would be difficult to ascribe to this amino-acid alone the propensity of the protein molecule to form a network with even a few cross-links (unless perhaps a chain mechanism of the type proposed by Huggins, Tapley and Jensen[4] were operative). We believe the gelation mechanism to be very much more complex. However, to the extent that cystine is involved, the present results, considered in conjunction with the fact that lanthionine is formed by the action of alkalis on wool[5] and other proteins, and with subsequent work on the reaction between disulphide links and alkalis[6-8], seem to be more consistent with the formation of single sulphur bonds than with the re-formation of disulphide linkages. The model experiments of Schöberl and Wagner[9] suggest a mechanism for the conversion of sulphydryl groups to single sulphur bonds. As only half the cystine in wool can be converted into lanthionine by the action of alkalis[10], it may be significant that the present maximum sulphur deficiency (time series, Table 2), when corrected for liberated sulphur, is again equivalent to about half the cystine in untreated casein.

Table 2. CYSTEINE AND CYSTINE IN ALKALI-TREATED CASEIN
(expressed in gm./100 gm. protein*)

pH Series (1 hr.)					Time series (pH 13·4)			
Treatment		Cysteine (*A*)	Cystine (*B*)	Original cystine −(*A* + *B*)	Period of reaction (hr.)	Cysteine (*A*)	Cystine (*B*)	Original cystine −(*A* + *B*)
NaOH concentration†	pH attained							
0·0	—	0·00	0·30	0·00	0	0·00	0·30	0·00
4·0	9·7	0·01	0·29	0·00	1	0·02	0·15	0·13
5·0	10·7	0·00	0·30	0·00	2	0·00	0·16	0·14
6·0	11·4	0·00	0·31	0·00	3	0·00	0·16	0·14
7·0	12·5	0·03	0·17	0·10	4	0·00	0·13	0·17
8·0	12·9	0·00	0·19	0·11	5	0·00	0·12	0·18
9·7	13·3	0·03	0·13	0·14	24‡	0·00	0·12	0·18
11·9	13·5	0·00	0·10	0·20	(gel.)	0·00	0·11	0·19
15·8	13·7	0·02	0·09	0·19				
19·8	13·9	0·00	0·13	0·17				

* Corrected for moisture and ash.
† In gm./100 gm. air-dry casein containing 9·6 per cent moisture, and 2·3 per cent ash.
‡ Two different preparations.

Recently, we have determined cystine and cysteine on a series of preparations of casein treated at 25° C. with sodium hydroxide at different *p*H values and for different periods. Again the casein to water ratio was 2 : 5; but for the *p*H series the period of reaction was only one hour. After re-precipitation with 1 *N* hydrochloric acid, dialysing and drying, the preparations were hydrolysed with 6 *N* hydrochloric acid for 24 hr., and the methods of Shinohara[3] were used to determine cystine and cysteine. Controls, in which the —SH groups were blocked by mercuric chloride, were used to account for the colour of the hydrolysate and the effect of extraneous reducers on the molybdate-free phospho-18-tungstic acid. Extinction coefficients were measured at 700 mμ. The results are shown in Table 2. In view of possible oxidation of sulphydryl groups during precipitation and hydrolysis of the preparations, the distribution of sulphur between cystine and cysteine is less significant than the figures in columns 5 and 9, which represent the amounts of the original cystine sulphur no longer in the form of sulphydryl or disulphide groups. It can be seen from the *p*H series that the original cystine

This problem is receiving further attention, and we hope to discuss it elsewhere in conjunction with other observations on the mechanism of protein gel formation.

H. G. HIGGINS
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Division of Forest Products,
Commonwealth Scientific and
Industrial Research Organization,
Melbourne. Dec. 21.

[1] Plomley, K. F., Higgins, H. G., and Hayes, J. F., *Nature*, **167**, 224 (1951).
[2] Wormell, R. L., *Nature*, **167**, 817 (1951).
[3] Shinohara, K., *J. Biol. Chem.*, **109**, 665 (1935); **112**, 671 (1936).
[4] Huggins, C., Tapley, D. F., and Jensen, E. V., *Nature*, **167**, 592 (1951).
[5] Horn, M. J., Jones, D. B., and Ringel, S. J., *J. Biol. Chem.*, **138**, 141 (1941); **144**, 87 (1942).
[6] Cuthbertson, W. R., and Phillips, H., *Biochem. J.*, **39**, 7 (1945).
[7] Lindley, H., and Phillips, H., *Biochem. J.*, **39**, 17 (1945).
[8] Barbu, E., and Macheboeuf, M., Abstracts Int. Cong. Biochem., Cambridge, 1949, p. 145.
[9] Schöberl, A., and Wagner, A., *Chem. Ber.*, **80**, 379 (1947).
[10] See Speakman, J. B., in "Fibre Science", 292 (Textile Institute, Manchester, 1949).

FORTHCOMING EVENTS

Wednesday, June 18

ROYAL METEOROLOGICAL SOCIETY (at 49 Cromwell Road, London, S.W.7), at 5 p.m.—Mr. R. J. Taylor: "The Dissipation of Kinetic Energy in the Lowest Layers of the Atmosphere"; Mr. R. Murray and Mr. D. H. Johnson: "Structure of the Upper Westerlies—a Study of the Wind Field in the Eastern Atlantic and Western Europe in September 1950".

Thursday, June 19

ROYAL SCOTTISH FORESTRY SOCIETY (in the Meeting Pavilion, Room B, Royal Highland Show, Kelso), at 2 p.m.—Annual Business Meeting; Major C. P. Ackers: "Progress in Forestry".

ROYAL SOCIETY (at Burlington House, Piccadilly, London, W.1), at 4.30 p.m.—Scientific Papers.

Friday, June 20

SOCIETY for ENDOCRINOLOGY (at Cambridge).—Symposium on "The Posterior Pituitary". (Further information from Prof. N. F. Maclagan, Westminster Medical School, Horseferry Road, London, S.W.1.)

Saturday, June 21

BIOCHEMICAL SOCIETY (in the School of Biochemistry, Tennis Court Road, Cambridge), at 11 a.m.—Scientific Papers.

APPOINTMENTS VACANT

APPLICATIONS are invited for the following appointments on or before the dates mentioned:

LECTURER IN ORGANIC CHEMISTRY—The Professor of Chemistry, Trinity College, Dublin (June 28).

LECTURERS (2, Grade II or III) IN ELECTRICAL ENGINEERING (for one post, a POWER ENGINEER with an interest in electrical measurements would be preferred; for the other, qualifications in high frequency radio are desired)—The Registrar, The University, Bristol 8 (June 28).

TUTORIAL RESEARCH STUDENTSHIP IN MATHEMATICS (pure or applied)—The Principal, Royal Holloway College, Englefield Green, Surrey (June 28).

AGRONOMIST (with not less than four years university training in agriculture and natural science, and experience in statistical techniques for design and analysis of field experiments) for group of estates in North Borneo under abaca, rubber and other crops—Personnel, Colonial Development Corporation, 33 Dover Street, London, W.1, quoting Serial No. 125 (June 30).

ASSISTANT IN BIOCHEMISTRY—The Secretary, The University, Aberdeen (June 30).

PHYSICIST for work in the X-Ray Department—The Medical Superintendent, Royal Infirmary, Dundee (June 30).

NORTH THAMES GAS BOARD RESEARCH FELLOWSHIP IN GASEOUS FUELS AND COMBUSTION—The Registrar, Imperial College of Science and Technology, Prince Consort Road, London, S.W.7 (July 1).

RADIATION, LTD., RESEARCH FELLOWSHIP IN GASEOUS FUELS AND COMBUSTION—The Registrar, Imperial College of Science and Technology, Prince Consort Road, London, S.W.7 (July 1).

OFFICER-IN-CHARGE (with either (*a*) a degree in statistics, or in mathematics or economics or other appropriate main subject combined with statistics, or (*b*) a degree in mathematics, economics, or other appropriate subject coupled with whole-time employment thereafter for at least twelve months continuously on statistical work) OF THE STATISTICAL SECTION of the Public Health Department—The Medical Officer of Health (PH/D.1), London County Council, County Hall, London, S.E.1 (July 5).

READERSHIP IN PHYSICS at the Royal Free Hospital School of Medicine—The Academic Registrar, University of London, Senate House, London, W.C.1 (July 9).

ASSISTANT LECTURER IN THE DEPARTMENT OF ZOOLOGY—The Registrar, Queen Mary College, Mile End Road, London, E.1 (July 10).

ASSISTANT LECTURERS (2) IN ZOOLOGY in the Department of Biology, Makerere College (University College of East Africa)—The Secretary, Inter-University Council for Higher Education in the Colonies, 1 Gordon Square, London, W.C.1 (July 12).

FARM MANAGER (preferably with a degree in agriculture, and experience of tropical agriculture, stock management and farm machinery) IN THE DEPARTMENT OF AGRICULTURE, University College, Ibadan, Nigeria—The Secretary, Inter-University Council for Higher Education in the Colonies, 1 Gordon Square, London, W.C.1 (July 12).

SCIENTIST (Grade I), a SCIENTIST (Grade II), and a SCIENTIST (Grade III), at the Central Research Establishment II, Isleworth, Middx.—The National Coal Board, Establishments (Personnel), Hobart House, Grosvenor Place, London, S.W.1, endorsed TT/479 (July 24).

GENECOLOGIST (Senior Scientific Officer or Scientific Officer grade) (with an honours degree in pure or applied botany, preferably with postgraduate training in genetics and ecology) in the Herbage Plant Department, to make a special study of the influence of environmental factors upon the hereditary composition of intra-specific populations, and a PLANT SOCIOLOGIST (Scientific Officer grade) (with an honours degree in botany or agriculture and some knowledge of genetics, ecology and statistical methods) to assist the Genecologist and in particular to study the arrangement and composition of plant populations in the field—The Secretary, Scottish Society for Research in Plant Breeding, Craigs House, Corstorphine, Edinburgh 12 (July 31).

SENIOR LECTURER OR LECTURER IN ANIMAL HUSBANDRY at the University of Sydney—The Secretary, Association of Universities of the British Commonwealth, 5 Gordon Square, London, W.C.1 (July 31).

SENIOR SCIENTIFIC OFFICER or SCIENTIFIC OFFICER (a first- or second-class honours degree in chemistry or biochemistry is essential, and experience of intermediary carbohydrate metabolism would be an advantage) for fundamental research on enzymes—The Secretary, Rowett Research Institute, Bucksburn, Aberdeenshire (August 1).

ASSISTANT (Grade B) FOR MATHEMATICS to degree standard—The Clerk to the Governors, South-East Essex Technical College and School of Art, Longbridge Road, Dagenham, Essex.

CHEMIST for work involving the flow-sheeting of chemical processes from chemical and chemical engineering research and development data, and advising on details during the design of production plants—The Ministry of Supply, Division of Atomic Energy (Production), Risley, Warrington, Lancs, quoting Ref. 340.

INSPECTORS OF AGRICULTURE in the Ministry of Agriculture, Sudan—The Sudan Agent in London, Wellington House, Buckingham Gate, London, S.W.1, endorsed 'Inspector of Agriculture 406'.

RESEARCH ASSISTANT for work on the microbiological or biochemical aspects of work on vitamin B_{12} and megaloblastic anæmia—The Registrar, King's College, Newcastle-upon-Tyne.

SCIENTIFIC and ASSISTANT SCIENTIFIC OFFICERS, EXPERIMENTAL and ASSISTANT EXPERIMENTAL OFFICERS, for work on combustion and heat transfer in domestic appliances, research on smokeless combustion of bituminous coal and various aspects of domestic heating—The Assistant Secretary, British Coal Utilization Research Association (Ref. A. 14), Randalls Road, Leatherhead, Surrey.

REPORTS and other PUBLICATIONS

(*not included in the monthly Books Supplement*)

Great Britain and Ireland

The Artificial Satellite. Edited by L. J. Carter. (Proceedings of the Second International Congress on Astronautics, London 1951.) Pp. iv+74. (London: British Interplanetary Society, 1952.) 5*s*. 6*d*. [284

Department of Scientific and Industrial Research. Report for the Year 1950–51. (Cmd. 8494.) Pp. 271. (London: H.M. Stationery Office, 1952.) 7*s*. 6*d*. net. [284

A List of British Mammals. By T. C. S. Morrison-Scott. Pp. 24. (London: British Museum (Natural History), 1952.) 2*s*. [284

Question: a Journal. Edited by H. Westmann. Vol. 4, No. 2: Freedom and Responsibility? By Prof. H. D. Lewis, H. J. Blackham, Dr. J. Bronowski and Wells Coates. (Published for the Present Question Conference, Ltd.) Pp. 105–216. (London: Hammond, Hammond and Co., Ltd., 1952.) 2*s*. 6*d*. [284

British School of Archæology at Athens. Annual Report of the Managing Committee for the Session 1950–1951; Archæology in Greece, 1950–1951. By J. M. Cook. Pp. 60. (London: British School of Archæology at Athens, 1952.) [304

Department of Scientific and Industrial Research. Report of the Food Investigation Board with the Report of the Director of Food Investigation for the Year 1950. Pp. iv+44. (London: H.M. Stationery Office, 1952.) [15

Institution of Metallurgists. The Principles of Extraction and Refining of Metals: Lectures delivered at the Institution's Refresher Course, 1950. Pp. 102. (London: Institution of Metallurgists, 1952.) [15

Other Countries

Official Records of the World Health Organization. No. 38: The Work of WHO 1951; Annual Report of the Director-General to the World Health Assembly and to the United Nations. Pp. iv+200+16 plates. (Geneva: World Health Organization; London: H.M. Stationery Office, 1952.) 9*s*.; 1.25 dollars; 5 Sw. francs. [304

Bulletin of the American Museum of Natural History. Vol. 99, Article 2: The Triassic Coelacanth Fish *Diplurus*, with Observations on the Evolution of the Coelacanthini. By Bobb Schaeffer. Pp. 25–78+plates 5–16. (New York: American Museum of Natural History, 1952.) 1.25 dollars. [55

Beach Erosion Board: Corps of Engineers. Technical Memorandum No. 12: Durability of Steel Sheet Piling in Shore Structures. By Albert C. Rayner and Culbertson W. Ross. Pp. iv+17+A.34. (Washington, D.C.: Government Printing Office, 1952.) [55

Conseil Permanent International pour l'Exploration de la Mer. Rapports et procès-verbaux des réunions, Vol. 130. 1ère partie: Procès-verbaux (Octobre 1951); 2ème partie: Rapport administratif (1950). Pp. 46+38. (Copenhague: Andr. Fred. Høst et fils, 1952.) 12.50 kr. [55

University of Illinois Engineering Experiment Station. Bulletin Series No. 393: Investigation of the Pressure Characteristics and Air Distribution in Box-type Plenums for Air Conditioning Duct Systems. By Prof. Stanley F. Gilman, Prof. Ross J. Martin and Prof. Seichi Konzo. Pp. 79. 80 cents. Bulletin Series No. 396: Studies of Slab and Beam Highway Bridges, Part 3, Small-Scale Tests of Shear Connectors and Composite T-Beams. By Prof. Chester P. Siess, Prof. Ivan M. Viest and Prof. Nathan M. Newmark. Pp. 135. 1 dollar. Bulletin Series No. 397: Performance of a Gas-fired Forced-air Heating System in Research Residence No. 1. By Prof. Seichi Konzo, George H. Green, Prof. Robert W. Roose and Morris E. Childs. Pp. 48. 60 cents. (Urbana, Ill.: University of Illinois, 1951–1952.) [55

Catalogues

Catalogue of Books on Agriculture, Horticulture, Animal Husbandry and Veterinary Science. Pp. 36. (London: H. K. Lewis and Co., Ltd., 1952.)

Laboratory Super-Centrifuges. (Bulletin 152.) Pp. 4. (Stroud: Sharples Centrifuges, Ltd., Woodchester, 1952.)

A Selection of Scientific Apparatus exhibited at the British Industries Fair, May 1952. Pp. 27. (Wembley and Birmingham: W. and J. George and Becker, Ltd., 1952.)

Price List of Biological Stains and Reagents. (Price List A.) Pp. 28. (London: George T. Gurr, Ltd., 1952.)